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Birds of the Diamantina River and Associated Channel Country Wetlands of South Australia

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Pelicans at Diamantina River waterhole May 2015; Sedges on the Warburton River April 2014

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Contents

List of Tables

List of Figures

Abstract

A survey of birds in riverine and associated landscapes of the Diamantina River, Warburton Creek and Kallakoopah Creek in the Far North of South Australia was conducted from 2014 to 2016. The study area lies at the lower end of the extensive Georgina-Diamantina catchment, part of the large internally draining Lake Eyre Basin. The main objectives of the study were to 1) document the distribution, richness, abundance and diversity of birds and bird assemblages, 2) quantify the relationships between birds and environmental variables, 3) determine the main organising and constraining influences on bird community structure and composition, 4) describe facets of ecological connectivity and drought refuges important to sustaining bird populations in the region, and 5) consider the management and conservation needs of significant birds and bird habitats. Birdlife along these rivers had received little survey effort and ornithological attention compared with Cooper Creek (the other major river system in the Lake Eyre Basin), and so comparisons could be made with that system. Over three autumn fieldtrips, each of 18 to 20 days, 24 sites were visited at which two to six transects were established in three broad habitats (riparian, floodplain, sand dune). A total of 83 bird transects was established, and 142 counts of landbirds were obtained from 43 visits to sites. Semi-quantitative vegetation and habitat details were recorded along each transect. Ad hoc observations of waterbirds were made where suitable habitat occurred, but as drought conditions ensued over most of the study period, waterbirds were not numerous. Linear mixed models (REML) were used to analyse bird community response in relation to survey design factors and measured habitat variables. Direct and indirect ordination and other multivariate analyses were used to model changes in composition between sites.

Over 150 species of birds were recorded, most of which were detected at survey sites. Observations of rare and threatened species were made, and several extensions of range were recorded. Observations of national significance were Curlew Sandpiper (Endangered), and Grey Falcon and Painted Honeyeater (Vulnerable), while historical observations of Plains-wanderer and Australian Painted Snipe (Endangered) also attest to the national conservation significance of the region. An observation of Spotted Bowerbird along the Diamantina River was highly significant as this species had been considered extinct in South Australia. Cattle Egret, Tawny Grassbird, Golden Whistler and Olive-backed Oriole were new species for the region marking significant range extensions. Further sightings were collected of a little known population of Red-tailed Black-Cockatoo, regarded as Endangered in the South Australian Arid Lands ('Outback') region of northern South Australia.

A firm expectation with regard to the variation in landbird species richness along the length of the river system was not upheld. Previous research on Cooper Creek had found a decrease in landbird richness with distance downstream, explained by the decline in mean annual streamflow and consequent loss of productivity and Coolibah density and vigour. However, in this study, highest landbird species richness was found in riparian environments in the lower portions of the Warburton River, which only partly could be attributed to destocking on Kalamurina Wildlife Sanctuary over the past eight years. Another reason for the unexpected result probably concerns the different hydrology of the Diamantina-Warburton river in that the decline in mean annual discharge between the state border and Lake Eyre is not nearly as great as it is in Cooper Creek, which rarely flows into Lake Eyre. Landbird species richness was positively correlated with many habitat variables, most important of which included the cover of the following plants – Broughton Willow, Coolibah, Lignum, mistletoes, and several sub-shrubs. The number of small tree species in the mid canopy was also an important predictor of higher landbird richness, as were the abiotic variables, litter cover and fallen dead timber.

Habitat type and year of survey proved to have the largest influence on bird species richness and abundance, and also on community composition. Landbird diversity and abundance steadily increased over the three years, for reasons which were not entirely apparent, but may have been partly due to drought refuge value of the rivers as the drought intensified in the wider region (in 2015). While there was no distinct assemblage of birds associated with floodplain environments, a small number of species showed a distinct habitat preference for sand dunes, and two plant species, Sandhill Canegrass and Umbrella Wattle, were positively associated with higher bird species richness in sandy environments.

Since the distribution, abundance and vigour of riparian plant species are under direct control of the hydrological regime, and given the riparian vegetation's critical role in providing habitat for the rich riparian bird assemblages found in the study area,

the primacy of hydrology in ultimately contributing to patterns of bird community structure and organisation is acknowledged. Maintaining the natural flow regimes of these rivers will be essential to maintaining healthy bird populations and communities.

1 Introduction

This report documents a three year study of birds and faunal habitats in the riparian, floodplain and wetland ecosystems of the Diamantina-Warburton river system in the Far North East of South Australia. The region is renowned for a major example of Channel Country wetland, namely Goyder Lagoon, that occupies a large proportion of the Clifton Hills Pastoral Lease in the central-northern parts of the study area depicted in Figure 1. Over a three-year period, 2014-16, research was conducted on four working cattle stations – (from north to south) Pandie Pandie and Alton Downs, Clifton Hills, and Cowarie – and a fifth property, Kalamurina Wildlife Sanctuary (operated as a cattle station until its purchase by the Australian Wildlife Conservancy in 2007) that extends from the middle reaches of the Warburton River downstream to Lake Eyre (Figure 1). The study area is wholly contained in the Lake Eyre Drainage Basin, and the Diamantina-Warburton river system forms the lower portions of the Georgina-Diamantina river catchment (Georgina/Diamantina Catchment Committee 2000). It and the Cooper Creek river catchment are the two largest river systems in the Lake Eyre Basin and arid Australia (Kotwicki 1986; McMahon *et al.* 2008b), and both catchments contain vast, intermittently-flooded wetlands of global biodiversity and heritage significance (Kingsford & Porter 1993; Kingsford *et al.* 1999a; Reid 1994, 2010; Morton *et al.* 1995a,b; Costelloe *et al.* 2004; Robin *et al.* 2010; Department of Environment and Resource Management 2011).

The major rivers of the Lake Eyre Basin are unique globally on account of their naturalness and high degree of flow variability (Puckridge *et al.* 1998, 2000; Costelloe *et al.* 2006; McMahon *et al.* 2008a, b). Invasive weeds and exotic aquatic fauna are few (Costelloe *et al.* 2004; Mancini 2013; Schmarr *et al.* 2013), and particularly in the Georgina-Diamantina catchment, broad-acre clearance of native vegetation and building of major dams have been minimal (Department of Environment and Resource Management 2011). Despite the extreme irregularity and episodic nature of streamflows in the Georgina-Diamantina catchment, and the consequent boom-bust, pulsed nature of ecological responses (Kingsford *et al.* 1999a; Reid 2010; Reid *et al.* 2010), connectivity along the drainage networks remains high, probably partly as a result of evolutionary filtering whereby the contemporary biota consists of those organisms that evolved strategies for coping with frequent periods of no-flow and disconnection between residual waterholes. Tolerance of high salinities and recolonisation capabilities among the native fish (Wager & Unmack 2000; McNeil & Schmarr 2009) and dispersive capabilities of Australian inland waterbirds (Kingsford & Norman 2002; Roshier *et al.* 2002) epitomise such strategies. Therefore, the functional connectivity of Lake Eyre Basin rivers remains high, due largely to their hydrological integrity or, as the Lake Eyre Basin condition assessment found in 2008, the rivers' low level of hydrological modification means that critical aquatic ecosystem processes remain intact (http://www.lakeeyrebasin.gov.au/resources/brochures-and-factsheets).

The South Australian sections of Cooper Creek and the Diamantina-Warburton make for an interesting comparison and are quite different in gross geomorphology, hydrology and ecology. Because the current study has a broadly similar scope and used similar methodologies to that of the recent Cooper Creek study (summarised by Mancini 2013 and Agnew *et al.* 2014), direct comparisons between the results of the two studies are possible and will be presented in the Discussion. Goyder Lagoon is a classic example of the Channel Country, prevalent in the lower reaches of the three main rivers – Georgina-Eyre, Diamantina, Cooper – in Queensland, but not along South Australian parts of the Cooper. In contrast, the extensive series of freshwater lakes and channels along the Cooper – the Coongie Lakes (Reid & Gillen 1988; Reid & Puckridge 1990) and Kanowana Lakes (Gillen & Drewien 1993) – are unique in Australia and probably the world for their number and climatic and landscape context (Morton *et al.* 1995a). Apart from Goyder Lagoon, the Diamantina and Warburton rivers have a much more continuous channelized morphology than the Cooper downstream of Innamincka, and consequently flows are more rapid and flow paths more direct in the Diamantina and Warburton. Accordingly Lake Eyre receives regional inflows from floods in the Diamantina-Warburton system far more frequently (approximately once every two years) than it does from Cooper Creek (Kotwicki 1986; McMahon *et al.* 2008b). The Cooper takes a much more roundabout course towards Lake Eyre as it negotiates the dunes of the Strzelecki Desert and consequently has gentler topographic gradients along most of its path (McMahon *et al.* 2008b), and delivers significant amounts of water to Lake Eyre only once about every 10 to 15 years (Kotwicki 1986; Badman 1989). Transmission losses along the Cooper are much greater than along the Georgina and Diamantina rivers (Kotwicki 1986; McMahon *et al.* 2008b).

In terms of characteristic biota and vegetation patterns, Cooper Creek and Diamantina River have some major differences. The River Red Gum does not naturally grow in South Australian sections of the Eyre Creek, Diamantina River and Warburton River, whereas it is the dominant tree of upper parts of Cooper Creek in the State, while two other woody perennial plant species are restricted to the Cooper drainage in South Australia, namely the Sour Plum (*Owenia acidula*) and River Paperbark (*Melaleuca trichostachya*) (all three are found higher in the Georgina-Diamantina catchments, in Queensland). Five sedentary riparian bird species are restricted to upper parts of Cooper Creek in the Far North East of South Australia, namely Barking Owl, Australian Ringneck, Brown Treecreeper, Black-chinned Honeyeater and Jacky Winter. In no case is there an ecological equivalent that occupies the Diamantina-Warburton system in South Australia, and so we might expect the avifauna of the riparian woodlands in the study area to be less diverse than found in the comparable study of Cooper Creek (Reid & Gillen 2013).

Partly because of the restricted distributions of five bird species to upper parts of the Cooper, Reid and Gillen (2013) found a strong relationship for both bird species richness and community composition with longitudinal position of study sites along the river. Landbird communities were more diverse in upper parts of the Cooper, and the composition of riparian bird communities at four sites in the lowest portions visited (lakes Hope-Killalpaninna district) were distinctly different to those upstream. There were additional riparian species, common along upper and middle sections of the Cooper that did not occur in the lower reaches, e.g. Peaceful Dove, Grey Shrike-thrush and Restless Flycatcher. These results were explained by the decrease in woody vegetation cover and vigour and also by the loss of characteristic tall shrub and low tree species in the riparian zones in lower parts of the Cooper, a function of the transmission losses (Knighton & Nanson 1994) and declining discharge phenomenon of Lake Eyre Basin rivers. Based on these findings, and given the Diamantina River exhibits a similar phenomenon of declining discharge with distance downstream in its South Australian reaches (Costelloe *et al.* 2006; McMahon *et al.* 2008b), we expected to find a similar gradient in riparian bird community richness and composition along the Diamantina-Warburton system in this study. However, with Goyder Lagoon in the middle of the study area and being such an extensive area of floodouts, braids and minor channels, contrasting sharply with the generally deeply channelized portions of the study area upstream (Diamantina) and downstream (Warburton and Kallakoopah Creek), this raises an alternative expectation. The riparian bird communities, and more generally the landbird fauna, of sites in Goyder Lagoon could be expected to be more dissimilar from those of the channelized portions of the study area than the differences in bird composition between the Diamantina and Warburton sections.

The birds of the Diamantina River are much less studied than those of Cooper Creek, particularly in South Australia. The birdlife along the Birdsville Track has been better documented than along the adjacent Diamantina and Warburton rivers. Easy access to parts of Cooper Creek from Innamincka and the progressive dedication of Innamincka Regional Reserve and Malkumba-Coongie Lakes National Park in recent decades have allowed ornithologists to visit Cullyamurra Waterhole and other waterholes and wetlands around Innamincka and along the North West Branch, and so document many observations (reviewed by Reid 2000). Major studies of the Coongie Lakes (Reid & Gillen 1988; Reid & Puckridge 1990) and middle and lower portions of Cooper Creek in South Australia (Badman 1989) have not had their parallel in the Diamantina-Warburton study area. Also the annually conducted Eastern Australian Aerial Waterbird Survey (Braithwaite *et al.* 1985; Kingsford *et al.* 1999b) includes the Cooper Creek drainage but not the Georgina-Diamantina catchment. A few aerial surveys of waterbirds in Goyder Lagoon have been conducted since 2000 (Reid & Jaensch 2004; Reid *et al.* 2009) but not widely published. This study aimed to redress some of these gaps in knowledge, particularly with respect to the distribution of sedentary landbirds associated with riparian and wetland habitats. The prevailing dry conditions until the final year of the study precluded any major focus on waterbirds in the region.

In terms of systematic research on the ecology of landbirds along the major rivers in the South Australian Lake Eyre Basin, particularly the controls on their distribution and abundance, the opportunity was presented in this study to make quantitative comparisons between Cooper Creek and the Diamantina-Warburton system about diversity, abundance and bird-habitat relationships. The distribution and abundance of River Red Gum and Coolibah proved to be the dominant structuring forces shaping bird community diversity and composition along Cooper Creek (Reid & Gillen 2013), and so it was anticipated that Coolibah would be the most significant plant influencing bird communities in the Diamantina-Warburton system. By adopting the same methodology for this study as used in the Cooper Creek study, we would be able to compare directly estimates of abundance and species richness across sites in both study areas. Furthermore, with the benefit of repeat visits to a range of sites over three years, the present study would allow some understanding of community dynamics to be obtained. This aspect was considered especially important in the context of an under-studied system.

Another consequence of the paucity of ornithological work in the study area, particularly in riverine, floodplain and wetland habitats, is the difficulty it poses to making comprehensive conservation assessments. For birds in the region there are three authoritative lists of threatened and near-threatened taxa that can be consulted, namely the Commonwealth's *EPBC Act, 1999* (http://www.environment.gov.au/epbc/), the South Australian *National Parks and Wildlife Act, 1972* (e.g. Gillam & Urban 2013), and the *Action Plan for Australian Birds 2010* (Garnett *et al.* 2011). The first two carry statutory authority, while the third is the most current and comprehensive assessment of all non-vagrant Australian birds' conservation status based on *IUCN* criteria (Garnett 2013). Gillam & Urban (2013) have comprehensively documented the occurrence and population trends of all threatened plants and animals in the Outback Region of northern South Australia. Their assessments were made at the IBRA subregional scale using *IUCN* criteria, and our study area is mainly represented in three such regions, namely 'Diamantina-Eyre', 'Sturt Stony Desert' and 'Dieri' (Lake Eyre North, Kallakoopah Creek and lower Warburton). A brief review of their assessment is presented in this report. Conservation significance is not limited to individual taxa, and the importance of the region's wetlands to sustaining Australian waterbird populations is highlighted. The identification of significant bird populations and faunal habitats, and consideration of management strategies that could improve their prospects or condition and health, is a major focus of the broader funded study.

Although (anticipated) differences between aspects of the ecology of Cooper Creek and the Diamantina-Warburton system have been emphasised in preceding paragraphs, there are undoubtedly many similarities, while also the connections between the two river systems, particularly for mobile organisms like birds, are likely to be highly significant (see next section). One striking similarity between the two systems is the narrow ribbon-like distribution of wooded riparian vegetation along the major watercourses. Riparian woodlands have very high ecosystem-function, cross-scale connectivity and conservation significance (Jansen & Robertson 2001a; Capon *et al.* 2013). Wooded riverine corridors are especially significant for landbirds in arid and semi-arid Australia (Reid & Gillen 1988, 2013; Reid *et al.* 1990; Mac Nally 1990; Brandle & Reid 1998; Woinarski *et al.* 2000; Jansen & Robertson 2001b, 2005; Pavey & Nano 2009; Smith 2015), since these ecosystems generally have high species richness and complementarity (alpha and beta diversity) through the provisioning of an array of resources not found more widely through dry landscapes (e.g. structurally complex vegetation, hollows, water, shade and shelter, and a diversity and greater productivity of food types; e.g. Leigh *et al.* 2013). As well as supporting species-rich bird communities locally, their influence extends to biogeographic scales as demonstrated by Woinarski *et al.* (2000) in the semi-arid savannas of the Northern Territory, and in the eastern Lake Eyre Basin (Reid *et al,* 1990; Reid & Gillen 2013). The latter studies concluded that the presence of densely wooded, structurally diverse riparian zones along Cooper Creek and its tributary streams that fall from the Great Dividing Range had permitted the penetration of eastern Australian woodland bird species deep into arid Australia. This raises the possibility of some bird species, more typical of the northern savannas or wooded landscapes in the northern Lake Eyre Basin, occurring along the Diamantina River in the study area, with the Red-tailed Black-Cockatoo population on Pandie Pandie Station being one example (Reid 2000).

The generally north-south alignment of the Georgina-Diamantina catchment rivers also raises the possibility that woodland-dependent landbirds undertaking migratory and other dispersal movements may follow the courses of these rivers. Mobility among landbirds in arid Australia is widespread yet poorly understood (Keast 1959; Schodde 1982; Smith 2015), with relatively few species exhibiting precise, regular and long-distance twice-yearly migrations based on time of year which, within Australasia, involves northern movements in autumn and south in spring (Dingle 2004). Most long-distance movements within arid Australia are considered to be nomadic more than migratory although, as Griffioen & Clarke (2002) showed for south-eastern Australia, often there is a seasonal component to nomadic movements. In a study of birds across a variety of habitats in arid north-west New South Wales over four years, Smith (2015) classified 35% of species as nomadic. Although the design of the present investigation – one autumn survey per year over three years – did not allow bird movements to be a focus of study, it was anticipated that northern movements of some landbird species could be detected, and that the riparian corridors of wooded vegetation could be important in this respect.

1.1 Connectivity

Connectivity with regard to the current study and the region's fauna incorporates many dimensions and scales, from evolutionary and biogeographic to ecological. Some aspects in relation to landbirds and their use of the major rivers in the study area have been canvassed in the preceding section. Ecologically, there are lateral connections evident at local to landscape spatial scales, illustrated by the increased bird species richness in landscapes having significant stands and stretches of woody riparian vegetation. Locally there are many bird species which either use riparian vegetation for food, breeding and shelter (roosting) or regularly visit waters to drink while spending most time away from the rivers in adjacent habitats. Similarly there are many riparian bird species which utilise the resources of adjacent landscapes on an occasional basis. The biogeographic ranges of several landbird species are directly shaped and constrained by the large Lake Eyre Basin rivers as described above, while there are probably many woodland species which would either not occur in the study area in the absence of the large rivers and attendant riparian vegetation or occur at much lower frequencies and abundance. That riparian corridors may act as 'highways' for landbirds on the move is also a distinct possibility, and therefore the rivers may play important roles in connecting bird populations across different regions in Australia. The aquatic-dryland ecosystems interface is a highly significant facet of ecological connectivity, and the two-way transfer of energy and nutrients across riparian zones and adjacent floodplains has many pathways (Capon *et al.* 2013). One critical pathway for landbirds is the flow of energy from aquatic environments in the form of food, a phenomenon known as food web subsidy (Polis *et al.* 1997). One Australian study found about a half of all (dryland) vertebrate species, mostly birds, living in the riparian zone of two northern Queensland Gulf rivers were observed to feed on aquatic fauna (Leigh & Sheldon 2013), with some insectivores having a high dependency on the flying adult phases of aquatic insects.

For Australian waterbirds, many species of which can move continental distances (e.g. Waterman *et al.* 1971; Kingsford & Norman 2002; Roshier *et al.* 2002, 2006, 2008; Reid 2009, 2010; Pedler *et al.* 2014), the wetlands of Goyder Lagoon support periodically hundreds of thousands of individuals (Reid & Jaensch 2004; Reid *et al.* 2010), in response to large floods. Waterbirds are thought to move into this region and the wider Channel Country region primarily for the purpose of breeding (Roshier *et al.* 2002; Reid & Jaensch 2004; Reid *et al.* 2010), and probably gather from all parts of the continent, as has been deduced for the Australian Pelican across the wider Channel Country-Lake Eyre region (Waterman & Read 1992; Reid 2009). Channel Country wetlands, including Goyder Lagoon, provide important stopover habitat for migrating shorebirds, including Endangered species such as the Curlew Sandpiper (Reid 1984; Reid and Gillen 1988; Reid & Jaensch 2004; Reid *et al.* 1990, 2010; Badman 1987, 1989; Badman & May 1983; Kingsford & Porter 1993). Over 20 species of migratory shorebirds, protected under international treaties (JAMBA, CAMBA and ROKAMBA: Morton *et al.* 1995a; http://www.environment.gov.au/cgi-bin/sprat/public/publicshowmigratory.pl), and to which Australia is a signatory, have been recorded in the wetlands of the Far North East of South Australia (Reid *et al.* 1990).

Within the Channel Country, waterbirds appear to capitalise on the different timing of floods across the major rivers and Lake Eyre (Reid 2009, 2010; Reid *et al.* 2010; Kingsford *et al.* 2010), vacating one region as conditions become unsuitable (e.g. drying, high salinities) to relocate to an adjacent river system where rich feeding grounds are inundated more slowly or persist for longer periods after the passage of a major flood. Thus, a major flood-generating, rainfall event which is coincident across the upper parts of the Georgina, Diamantina and Cooper catchments will travel most quickly down the Diamantina-Warburton system, followed by flows down the Georgina River-Eyre Creek drainage, with floodwaters taking considerably more time to progress to the Coongie Lakes and lower reaches of Cooper Creek in South Australia (McMahon *et al.* 2008b; Reid 2010). Through satellite telemetry there is direct evidence now of an individual Grey Teal, initially caught and released at Lake Hope, which is known to have moved from Goyder Lagoon to the Coongie Lakes and back to Goyder Lagoon within the space of a year and travelling over 2000 km over that period (Roshier *et al.* 2006: Table 1; Fig. 5). The shifts in the timing of flooding, which become more pronounced in the lower reaches of these rivers, combined with annual differences in the location, intensity and timing of flooding rains in the upper (and all parts of the) catchments, create an unpredictable range of challenges and opportunities for waterbirds in the Lake Eyre Basin, but to which they appear to be well adapted. The relationships between waterbird movements and wetlands, both within arid Australia and across the entire continent, has been examined by D.A. Roshier and colleagues (Roshier *et al.* 2001a, 2001b, 2006, 2008; Roshier & Rumbachs 2004; McEvoy *et al.*

2015; see also Pedler *et al.* 2014) and, despite the often prolonged dry spells of wetlands in the interior, waterbirds view and use these intermittently inundated wetlands as dynamic, intermittently connected landscapes. Roshier *et al.* (2002) concluded that flooding in the Lake Eyre Basin wetlands exerts a considerable pull on waterbirds outside of the region, as shown by the range of responses of different functional groups within the north-western catchments of the Murray-Darling Basin over a three-year period – the high productivity of extensive areas of shallowly inundated floodplain wetlands (Puckridge *et al.* 2000) and increased chances of breeding success were cited as the probable pull factors.

1.2 Study Objectives

The primary aim of this study was to document the distribution, abundance and habitat use of birds in riparian woodlands along the Diamantina-Warburton river system and adjacent habitats, combining standard census (transect) procedures with *ad-hoc* observations. Specific objectives with respect to landbirds were:

- Quantify the distribution and abundance of landbird species in relation to systematic measures of habitat (vegetation, landform and ground layer variables);
- Develop an understanding of the key environmental factors that shape bird community composition, abundance and diversity, focussing on variations that occur systematically in relation to longitudinal position (between-sites), laterally across the floodplain (within-sites), and through time;
- Assess the influence and control of Coolibah (*Eucalyptus coolabah*), as a keystone species and habitat component, in shaping a) the distribution and abundance of bird species, and b) community assembly;
- Classify bird assemblages into a few discrete, habitat-based bird communities, to enable communication and summarisation of results for a range of audiences.

For all birds, including waterbirds, other objectives were:

- Document the diversity of birdlife in the study area and identify the major environmental influences and controls on the spatio-temporal distribution of individual species;
- Identify the bird species of regional, state and national conservation significance, and assess their status in the region;
- Identify significant faunal habitats and, from a management perspective, identify potential threatening processes that could contribute to loss of integrity and degradation of high-value habitats and refuges;
- Develop interpretation materials to inform the community of the importance of riparian habitats and refugial waterholes, and the roles they play in ecosystem function and biodiversity conservation;
- Identify knowledge gaps and further areas of research.

The opportunity was presented for a butterfly survey of waterholes to be undertaken, and so a final objective was to:

- Describe the composition and diversity of butterfly assemblages across a range of sites.

Structure of the report. Subject to a few subsequent taxonomic reappraisals avian nomenclature broadly follows Christidis & Boles (2008). A complete list of birds recorded during the survey, and their scientific names, is presented in Appendix 1.

2 Methods

Located in the Far North East of South Australia the study area is defined as the South Australian sections of the Georgina-Diamantina Catchment, from the mouth of the Warburton River at Lake Eyre north to the Queensland border, bounded broadly by 137° E to 140° E of longitude and 26° E to 28° E of latitude (Figure 1). Descriptions of the region's climate and environment are presented in companion reports. The project team recognised four management zones across the study area and as shown in Figure 1: Diamantina, Eyre, Goyder Lagoon, and Warburton, named after the dominant river or wetland in each zone. Four cattle stations ('Pandie Pandie', 'Alton Downs', 'Clifton Hills' and 'Cowarie') and a former cattle station, now a non-government wildlife reserve, Kalamurina Sanctuary, make up the bulk of the study area, while to the west of these properties and the major alluvial systems which are the focus of the study, lie the Simpson Desert Conservation Park and Regional Reserve. Physiographically three broad land systems can be recognised, namely the Simpson Desert dunefields, the Lake Eyre Basin alluvial systems, and Sturts Stony Desert consisting mainly of gibber plains with occasional low residual hills and breakaways. Source bordering dunes and other sandy/alluvial deposits are scattered in Goyder Lagoon and along most stretches of river. Four broad habitats defined by terrain were identified for stratification purposes at the outset, namely riparian, floodplain, dune and gibber plain. Not all terrain types were necessarily represented at each survey site.

Four of the region's major streams were subject to intensive site-based surveys, namely Eyre Creek, Kallakoopah Creek, Diamantina River and Warburton River, although only the last two were comprehensively surveyed. Twenty-four sites were surveyed one to three times between April 2014 and May 2016, and their spread across properties, management zones and years is presented in Table 1. Five sites – "Diamantina River Split" (DSPL), Andrewilla Waterhole (ANDR), Koonchera Waterhole (KOON), Ultoomurra Waterhole (ULTO) and "Cowarie Crossing" (COWC) – were visited in all years, although in some respects the combination of Kuncherinna Waterhole (KUNC) and 'Mona Downs' old homestead ruins (MONA) could be construed as replicate samples of the same reach, the sites being separated by less than four kilometres and lying on a continuous stretch of river (Kallakoopah Creek) – see Figure 1. Generally, less than 24 hours were spent at sites during the three annual surveys, as we moved from one site to the next on a daily basis. These time constraints sometimes precluded a comprehensive mix of transect locations and habitats ("subsites") being selected and studied during the first visit to a site. Accordingly extra subsites were incorporated on second visits to some sites. The full schedule of sampling visits to sites and subsites, along with the distribution of habitats among sites, is presented in Table 2.

Drought-breaking, flooding rains midway through the third year's survey left the work team stranded in the Andrewilla Waterhole area for seven days. Between 60 and 80 mm of rain were thought to have fallen across most of the study area on the night of 8/9 May 2016 (Birdsville officially recorded about 50 mm – Bureau of Meteorology). We managed to move to a new site at nearby Pelican Waterhole on 12 May, before being led back to Birdsville by Don Rowlands on 15 May. While stuck at Andrewilla, we took the opportunity to conduct bird censuses at the three transect subsites on four consecutive days. Most sites proved to be inaccessible after this, although we could access the Peraka Lakes area, Ultoomurra Waterhole and Cowarie Crossing. We established a new bird-survey site in the Peraka Lakes area, while other project staff boated to the established Yammakira Waterhole site and, forced to camp on Tippipilla Creek adjacent to the Birdsville Track one evening, we established a site there as an example of a highly ephemeral minor (but flowing) watercourse that drains off the gibber plains of Sturts Stony Desert. We also took the opportunity to revisit the Cowarie Crossing site and resample the transects 16 days after the first visit early in the fieldtrip. Location (mapped) names, precise locations and descriptions of sites and subsites are given in the Results. Fifteen sites (and 45 subsites) were surveyed in 2014, 14 (52) in 2015, and 14 (41) in 2016.

Table 1 Bird survey schedule and distribution of sites among management zones and major rivers or wetland complex

				Year			Location	
SiteCode	**Property**	**Management Zone**	**River - Wetland**	**2014**	**2015**	**2016**	**Latitude**	**Longitude**
DBYD	Pandie Pandie	Diamantina	Diamantina		X	X	26° 16.057' S	139° 23.510' E
PAND	Pandie Pandie	Diamantina	Diamantina	X			26° 7.332' S	139° 23.082' E
DSPL	Alton Downs (part Pandie Pandie)	Diamantina	Diamantina	X	X	X	26° 24.321' S	139° 23.740' E
ANDR	Clifton Hills	Diamantina	Diamantina	X	X	X	26° 32.201' S	139° 15.376' E
YAMM	Clifton Hills	Diamantina	Diamantina	X	X		26° 31.500' S	139° 26.380' E
TEPA	Clifton Hills	Eyre	Eyre	X	X		26° 40.383' S	138° 59.544' E
BURT	Clifton Hills	Goyder Lagoon	Goyder Lagoon		X		26° 35.309' S	139° 9.016' E
GOYD	Clifton Hills	Goyder Lagoon	Goyder Lagoon	X	X		26° 53.247' S	138° 58.156' E
KOON	Clifton Hills	Goyder Lagoon	Goyder Lagoon	X	X	X	26° 41.241' S	139° 30.190' E
PELI	Clifton Hills	Goyder Lagoon	Goyder Lagoon			X	26° 32.970' S	139° 13.067' E
PERA	Clifton Hills	Goyder Lagoon	Goyder Lagoon			X	26° 33.604' S	139° 30.905' E
YELP	Clifton Hills	Goyder Lagoon	Goyder Lagoon		X		27° 7.460' S	138° 42.584' E
TIPP	Clifton Hills	Other	Other			X	26° 59.545' S	139° 0.597' E
ULTO	Clifton Hills	Warburton	Warburton	X	X	X	27° 9.000' S	138° 43.628' E
COWC	Cowarie	Warburton	Warburton	X	X	X	27° 36.582' S	138° 18.474' E
KALA	Cowarie	Warburton	Warburton	X	X		27° 17.020' S	138° 33.036' E
STON	Cowarie	Warburton	Warburton	X	X		27° 27.358' S	138° 31.272' E
KUNC	Cowarie	Warburton	Kallakoopah	X			27° 21.876' S	138° 28.167' E
MONA	Cowarie	Warburton	Kallakoopah		X	X	27° 23.608' S	138° 27.244' E
MIAM	Kalamurina	Warburton	Warburton			X	27° 49.209' S	138° 11.133' E
POON	Kalamurina	Warburton	Warburton	X			27° 52.696' S	137° 54.382' E
TINN	Kalamurina	Warburton	Warburton			X	27° 53.307' S	138° 1.221' E
WADL	Kalamurina	Warburton	Warburton	X		X	27° 52.134' S	138° 8.825' E
YELL	Kalamurina	Warburton	Warburton	X		X	27° 42.293' S	138° 15.120' E

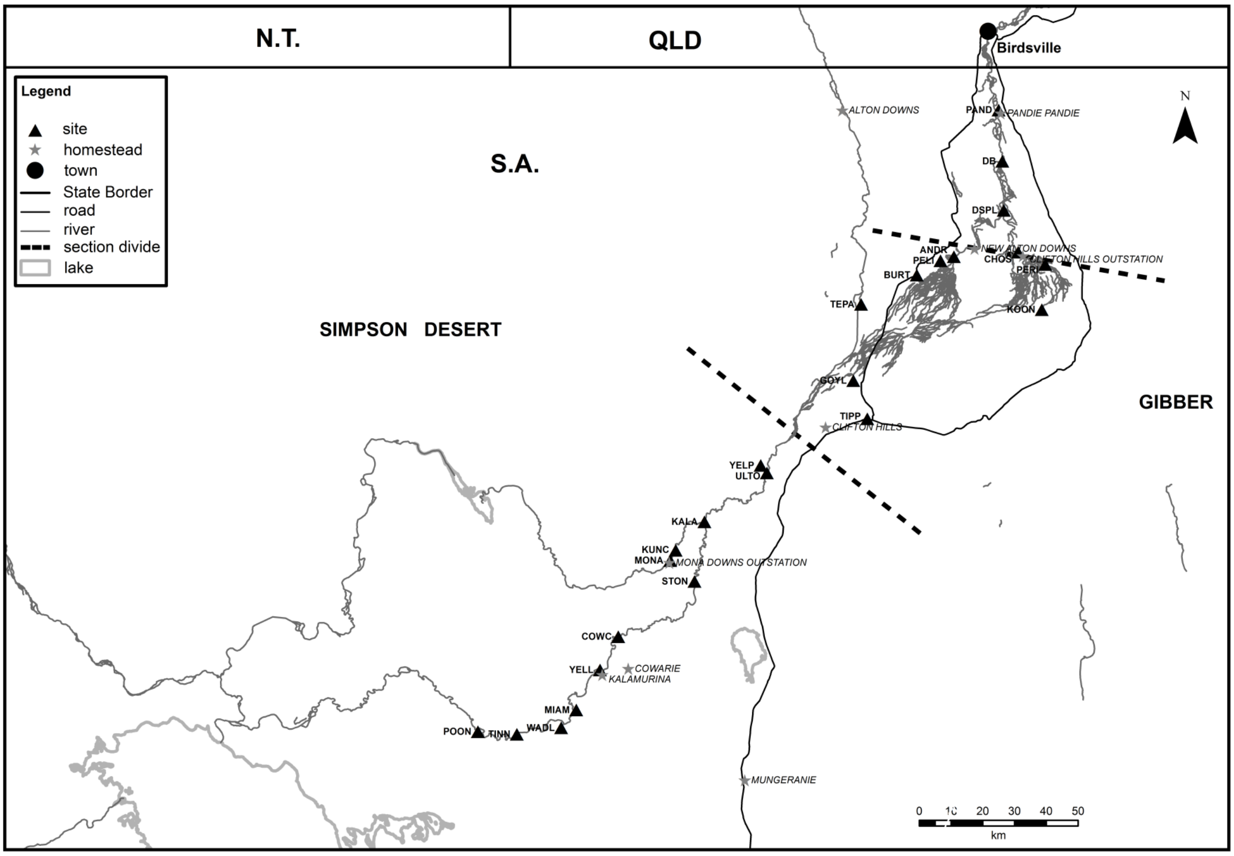


Figure 1 Map of study area showing major streams, study sites and management zones

Table 2 Year in which subsites and broad habitats were established and surveyed across sites

		Subsite Habitat Code					
SiteCode	**Year**	**Riparian - 1**	**Riparian - 2**	**Floodplain - 1**	**Floodplain - 2**	**Dune**	**Gibber**
DBYD	2015	DBYDR		DBYDO	DBYDP	DBYDD	
DBYD	2016	DBYDR	DBYDS	DBYDO	DBYDP	DBYDD	
PAND	2014	PANDR				PANDD	
DSPL	2014	DSPLR	DSPLS	DSPLO		DSPLD	
DSPL	2015	DSPLR	DSPLS	DSPLO		DSPLD	
DSPL	2016	DSPLR	DSPLS	DSPLO		*no access*	
ANDR	2014	ANDRR	ANDRS	ANDRO			
ANDR	2015	ANDRR	ANDRS	ANDRO			
ANDR	2016	ANDRR**	ANDRS**	ANDRO**			
YAMM	2014	YAMMR		YAMMO	YAMMF	YAMMD	YAMMH
YAMM	2015	YAMMR	YAMMS	YAMMO	YAMMF	YAMMD	YAMMH
TEPA	2014	TEPAR		TEPAO			
TEPA	2015	TEPAR		TEPAO		TEPAD	
BURT	2015	BURTR		BURTO	BURTP	BURTD	
GOYD	2014	GOYDR					GOYDG

		Subsite Habitat Code					
SiteCode	**Year**	**Riparian - 1**	**Riparian - 2**	**Floodplain - 1**	**Floodplain - 2**	**Dune**	**Gibber**
GOYD	2015	GOYDR	GOYDS	GOYDO			GOYDG
KOON	2014	KOONR		KOONO		KOOND	
KOON	2015	KOONR		KOONO		KOOND	
KOON	2016	KOONR		KOONO		KOOND	
PELI	2016	PELIR		PELIO		PELID	
PERA	2016	PERAR		PERAO		PERAD	
YELP	2015	YELPR		YELPO		YELPD	
TIPP	2016	TIPPR				TIPPD	
ULTO	2014	ULTOR		ULTOO			
ULTO	2015	ULTOR		ULTOO	ULTOP	ULTOD	
ULTO	2016	ULTOR		ULTOO	ULTOP	ULTOD	
COWC	2014	COWCR		COWCO	COWCF		
COWC	2015	COWCR		COWCO	COWCF	COWCD	
COWC	2016	COWCR*		COWCO*	COWCF*	COWCD	
KALA	2014	KALAR	KALAS	KALAO			
KALA	2015	KALAR	KALAS	KALAO			
STON	2014	STONR	STONS	STONO			STONG
STON	2015	STONR	STONS	STONO			STONG
KUNC	2014	KUNCR		KUNCO		KUNCD	
MONA	2015	MONAR	MONAS	MONAO			
MIAM	2016	MIAMR	MIAMS	MIAMO			
POON	2014	POONR		POONO		POOND	
TINN	2016	TINNR		TINNO		TINND	
WADL	2014	WADLR	WADLS	WADLO			
WADL	2016	WADLR	WADLS	WADLO		WADLD	
YELL	2014	YELLR	YELLS	YELLO			
YELL	2016	YELLR	YELLS	YELLO	YELLP		

* repeat sampled 16 days apart; ** repeat sampled three times (four counts in all), due to rain/flooding.
CHOSH was not in gibber, but in a mixed claypan/dunefield/outer floodplain habitat.

Features of the design of the survey were coded as factor variables for regression modelling of bird responses. Management Zone ('ManagZone') comprised the four regions shown in Figure 1. Although sites were distributed across five properties, the factor 'Prop' had four classes by placing 'Diamantina Split' waterhole in the Pandie Pandie group, thus eliminating Alton Downs. Habitat ('HabMaj') comprised the four classes described above (Table 2). A refinement of the habitat classification dividing each of Riparian and Floodplain into two classes, 'HabMin', was found to improve model fitting (details below).

2.1 Field Surveys

A complete birdlist was kept for each site on each fieldtrip and notes of less frequently encountered species seen while driving around the study area were also made. Any evidence of breeding activity was recorded.

Transects (Table 2) were established at sites to estimate the abundance of birds using the same methodology as Reid & Gillen (2013). Transect censuses were adopted because they are flexible and applicable to most habitats. Experience in the Far North East of South Australia (Reid 1984) had exposed the limitations of point-count techniques in open environments, since many birds flee at the observer's approach in the absence of sheltering/screening vegetation cover. Adopting the methods of Bibby *et al.* (1992), fixed-distance belt transects of 500 m length and 100 m width were established at each site. Because bird abundance varied considerably among but not within sites, a fixed time per transect was not strictly observed, but an allowance of 20-30 minutes was permitted per count. Transect start and end points were recorded with GPS, and observers walked steadily along the transect, recording all birds detected and identified (seen and heard, and numbers counted or estimated) within a few hundred metres. Generally, one transect count was completed at each subsite during each fieldtrip, with the exceptions noted above. Also a colleague with expertise in birds and butterflies participated in the second fieldtrip in 2015, allowing replicate bird counts at most transect locations. The senior author collected bird transect data on all fieldtrips at each established subsite, and Dr S. Bond conducted censuses at all but a few subsites in 2015. For all sightings the perpendicular distance from the transect midline to the point of detection was estimated. A distinction was made for birds observed flying between those passing through or over the site seemingly without stopping or foraging in the habitat being surveyed ('Out'), and those engaged in foraging activities ('In'). The former detections, although recorded and entered into a database, were excluded from calculations prior to estimating densities and statistical analyses.

Semi-quantitative vegetation and other habitat data were gathered at five points along each transect midline, placed approximately at the 50-, 150-, 250-, 350- and 450-m points. At each point in the surrounding estimated 30-m radius area, woody (perennial) shrubs and trees were identified to species and their mean height and cover class recorded (see Appendix 3 for the *pro-forma* sheet used). Five cover classes (modified from the Braun-Blanquet scheme), on a semi-logarithmic scale were used, namely < 1%, 1-5%, 5-20%, 20-50%, and > 50%. Two species of subshrub (*Enchylaena tomentosa* and *Einadia nutans*) and two species of hummock grass (*Triodia basedowii* and *Zygochloa paradoxa*) were also scored when present. For non-woody vegetation, three other plant groups were recognised, namely non-hummock grasses, reeds and sedges, and other herbs and forbs (including subshrubs). These plant groups, as well as amounts of litter, bare soil, and any rock strew, were also scored using the same cover classes. The presence of mistletoes (with their hosts) was also recorded. Finally using a three-tiered scoring system ("L" for limited/low, "M" for modest/medium, and "H" for high amounts), a rapid, rough assessment was made of the abundance of hollows and dead timber in three categories – standing, fallen and large, fallen and small – at the five points along each transect. Habitat assessments were made once, during the survey when the transect was established and first bird census taken.

2.2 Data Management

Transect count data were summarised in the first instance as the total number of birds of each species recorded per count, and these summaries are presented in the Results for each site. For each count, densities of individual species were calculated as the sum of individuals detected within the 100-m belt (and not flying over/through), expressed as number of individuals per hectare. Where a species was detected at the distance 50-100 m from the transect midline, but not within the central 100-m belt, the species was arbitrarily assigned a density of 0.1 birds/ha (calculated as one bird in the 10 ha surveyed in this case), regardless of how many individuals may have been counted in this distance band. Bird species observed at distances greater than 100 m from the transect midline, even if observed in the surveyed habitat during a transect count, were excluded from density estimation procedures. The density estimates of several flocking species – e.g. Diamond Dove, Tree Martin and Zebra Finch – were restricted to a maximum of 8 birds/ha at a few sites where their abundance was deemed unrealistically large; while these deflated estimates were used for subsequent analyses, the actual estimates are presented in the initial data summaries. Multivariate analyses were restricted to landbird species, and excluded nocturnal species and 'quails', as nocturnal and quail-like species (true quails and button-quails) could not be censused efficiently due to their cryptic behaviour. Density estimates for each visit to sites are presented in the Results at the scale of the habitat (subsite).

The abundances of most species recorded by the two observers during the second survey (2015) were so disparate, and also because only the main observer undertook counts across all three years, the density estimates presented in the main Results section are based only on these data. A comparison of the two observers' bird census data is given in Appendix 2.

For each transect subsite, geometric means were computed for the cover-abundance of all plant species and categories scored using the modified Braun-Blanquet system. The arithmetic mean of heights, with zeros excluded, was computed for each individual plant species. A ten-point, ordered-rank summary of the prevalence of hollows and the three dead timber categories was tabulated using the system shown in Table 3.

Table 3 Rank summary scoring system for prevalence of hollows and dead timber categories assessed at each transect subsite

Rank	Code	Strings of point scores (5 observations per subsite)							
0	N	Nil							
1	LLL	L	LL						
2	LL	LLL	LM	M					
3	L	LLLL	LLLLL	LLM	LLLM	LMM	LH	MM	H
4	LM	LLMM	LLLLM	MMM	HML				
5	ML	MMML	MMMLL	MMLLL	MMHLL	MHLLL			
6	M	MMMM	MMMMM	MMMML	MMMHL	MMMH	HHMM		
7	MH	MMMMH	MMMHH						
8	HM	HHH-							
9	H	HHHH-							

- indicates either absences or scores of "L" and/or "M" will results in the rank score shown (for 8 & 9)

2.3 Data Analyses

The complete species lists compiled for all site visits were examined as presence-absence data, focussing on three combinations of bird species – all species, and two complementary subsets, dividing the lists into waterbirds (Orders Anseriformes, Podicipediformes, Phalacrocoraciformes, Ciconiiformes, Gruiformes, excluding Australian Bustard, and Charadriiformes, excluding Little Button-quail) and landbirds. Species richness of the three combinations and in the proportionate richness of waterbirds were examined and analysed with one-way analysis of variance to test the hypotheses that these four measures of diversity varied across the three years of surveys (Year) and across management zones (ManagZone, having first taken the means of the response variables for sites with multiple visits across years). Species richness measures were log-transformed prior to anova tests, while proportionate waterbird richness, expressed as percentages, was left untransformed.

Similarity in assemblage composition between site visits was assessed with the Simple Matching Coefficient, (Jaccard Index of Similarity), expressed as percentages (e.g. Maron *et al.* 2005). Mean similarity between various groupings of the data (within and between Years, and within and between Properties within and between Years) was assessed to reveal the major sources of compositional variation through time and space. An objective classification of site visits, based on compositional differences computed as the Sørensen Index of Dissimilarity, was undertaken with the UPGMA clustering algorithm in PATN (Belbin 1995) to determine the major clusters of site visits based on assemblage affinities. Indirect gradient analysis of the same data (all species retained, across the 43 site visits) was performed with the semi-strong hybrid option of non-metric dimensional scaling (NMDS) in PATN (Belbin 1995). A three-dimensional ordination solution with stress < 0.2 was obtained with 100 random starts, and this solution was rotated to Principal Components so that the maximum amount of variability in assemblage composition would be spread along the first axis, and so help identify the major sources of variation and associated environmental influences. The species most influential in shaping the ordination patterns were examined using the Principal Axis Correlation (PCC) routine in PATN; this routine calculates, for each species in turn, the multiple correlation coefficient, R_m, of the relationship between the site visit scores (*x*, *y*, *z*) and the value of the species (0 or 1) for each site visit. A Monte Carlo permutation routine (MCAO in PATN, 1000 randomisations) was used to assess the notional significance of each correlation coefficient. Formal tests of the hypotheses that assemblage composition of site visits varied significantly across Year, Property and ManagZone were undertaken in the R statistical package, vegan, using the routine 'anosim' (Oksanen *et al.* 2011) with probabilities of significance determined by permutation (999 randomisations). Finally, canonical correspondence analysis (ter Braak 1986; using routine 'cca' in vegan: Oksanen *et al.* 2011) of the site visits presence-absence dataset was undertaken to visualise the joint effects of ManagZone and Year, both as factor variables, in ordination space, and as an independent check of the anosim tests (999 randomisations used in cca as formal tests of the effects of both factors). Given initial appraisal of the NMDS results had raised the possibility that Year may have been a significant influence on the spread of observations (site visits) along the third axis of the rotated ordination solution (presented in Results), this formal step was taken. Furthermore, given other results had shown there were 25 of the total 146 species which were recorded in one year only, and which were recorded only once ('singletons') or twice ('doubletons') out of the 43 site visits, and that therefore could have had large influence on tests of the structuring effect of year on assemblage composition in anosim and cca tests, the cca analysis was performed again having first removed all (31) singleton and doubleton species.

Analysis of Landbird Data

Species' density estimates for each survey at each subsite (transect) compiled from the senior author's observations provided the numerical data for most subsequent analyses. Where multiple samples were collected (two and four, respectively, at Cowarie Crossing and Andrewilla during the third survey and at a couple of other subsites in earlier surveys), data from the first transect count were used. Actual densities, with or without log-transformation, were used in subsequent analyses, when making quantitative comparisons between surveys, properties, management zones and habitats, and for some multivariate analyses. As well as the data for individual species, summary community statistics were computed, namely species richness and total abundance (the sum of all species' densities). Variations in species richness and total community abundance were summarised and compared directly, presented as tables and graphs, to reveal the major trends in the data, e.g. by comparison of means and standard errors between various groupings off the data. However, statistical inference was not pursued due to the multiple dependencies in the survey design. To account for the repeated-measures and hierarchical (habitats nested within Sites) features of the survey design, statistical modelling and inference were carried out in the lme4, mixed-modelling, software on the ***R*** platform (Bates *et al.* 2106). Only the community-level response variables – species richness and total bird abundance – were analysed, and inspection of both raw data and residuals from fitted models showed that the raw variable, species richness ('Rich'), and the square-root transformation of both variables ('sqrtS' and 'sqtAb'), conformed to a normal distribution, and so residual maximum likelihood (REML) linear models were fitted to these three responses.

REML Modelling

Tests of differences in total abundance and species richness over time, with Year as a factor and fixed effect, were undertaken using mixed models (REML) in lme4 for R, specifying individual slopes for each level of Year (as well as the estimated intercept for each site) as the random effects to account for the repeated-measures design (Bates 2010), and with subsite nested within Sites as a second random effect to account for the spatial hierarchical structure. Subsequent maximum likelihood comparisons with the simpler model that excluded Year from the random effects term revealed that the simpler model was preferred (explaining a similar amount of deviance), and so subsequent REML models specified Sites + subsite nested within Sites as the random effects (with only the intercepts for Sites estimated in the first random effects term). Tests for differences in richness and abundance between properties (Prop) and management zones (ManagZone) were undertaken in lme4 with this model, including the term for Year previously fitted. Tests for differences between habitats included the significant variables already fitted (Year and Prop). For REML models with more than one fixed effect, the interaction terms were also tested, although the results of these tests were treated with caution given the highly unbalanced design (Zuur *et al.* 2009). We used three habitat groupings and two property groupings, after initial modelling trials revealed there were marked variations in richness and abundance within the riparian and floodplain habitat classes, and also in an attempt to minimise the number of degrees of freedom used in subsequent, complex multi-variable models (details below). First, 'HabMin' had six levels, namely dune, gibber, major channel riparian, minor channel riparian, open floodplain, and denser floodplain (with at least moderate cover of woody shrubs and/or trees). Second, 'Hab2' comprised a riparian class and the rest. Similarly, since most of the variation in avian richness and abundance by property identity was between the Kalamurina Sanctuary and the working cattle stations, a 'Prop2' factor was used to simply discriminate between these two groups in some models.

The effects of individual habitat variables on bird richness and abundance were tested, one variable at a time, using the same approach as just described, except that interaction terms were not included. Only those 32 plant species (or groups) and habitat variables observed on at least seven transects were tested. Since some of these variables were strongly correlated with the habitat classification, these series of models were run three times, all with Year effects included, one without the habitat factor and one without habitat and property identity included in the model. The codes used for these habitat variables and their frequency across the 84 subsites are presented in Table 4

Table 4 Habitat codes

Habitat Code	Habitat Variable Full Name	Frequency
Cool	Coolibah	71
Bauh	Bauhinia, Queensland Bean-tree	16
Ac_sali	*Acacia salicina*	53
Ac_sten	*Acacia stenophylla*	50
At_hemi	*Atalaya hemiglauca*	11
Am_preis	*Amyema preissii*	18
Lys_exoc	*Lysiana exocarpi*	10
Ac_vict	*Acacia victoriae*	8
Er_bign	*Eremophila bignoniiflora*	20
Sant_lan	*Santalum lanceolatum*	27
Ac_lig	*Acacia ligulata*	29
Ac_murr	*Acacia murrayana*	8
Ch_auri	*Chenopodium auricomum*	37
Lignum	Lignum	60
omsb	Old man saltbush	15
senna	*Senna* (Cassia) spp.	10
Ench_Ein	*Enchylaena tomentosa* & *Einadia nutans*	50
Pt_atr	*Ptilotus sessilifolius*	7
Rh_spin	*Rhagodia spinescens*	7
Sen_cunn	*Senecio lanibracteus*	17
Cyn_flor	*Cynanchum floribundum*	7
Zyg_para	*Zygochloa paradoxa*	22
grasses	grass cover, excluding cane grass and spinifex	63
ephems	low ephemeral plant cover	81
litter	litter	84

Habitat Code	Habitat Variable Full Name	Frequency
baregrnd	amount of bare ground	84
sedges	sedge cover	17
hollows	hollow abundance	63
sawn	evidence of timber cutting	8
StandDT	amount of standing dead timber	69
FallLgDT	amount of fallen large timber	62
FallSmDT	amount of fallen small timber	76
Mist	mean cover of all mistletoe species	26

The last (33rd) variable, 'Mist', is a composite of the combined abundance of the three species of mistletoe observed on habitat transects, including the Coolibah specialist, *Diplatia grandibractea*, noted rarely.

A principal components analysis (PCA) of the 32 primary habitat variables across 84 subsites was used to summarise the major gradients in vegetation across the study area and to guide the REML modelling process in terms of selection of candidate habitat variables in complex models (see next paragraph). A multi-variable REML model of bird species richness using the first six PCA scores as candidate variables was built with forward stepwise selection procedures in lme4 (lmer function). The random effects terms were as specified previously, and the factors Year, Prop and HabMaj were first included.

More complex models, including as many individual habitat terms as possible, using forward stepwise selection, were fitted for the three response variables. The property and habitat factors could be dropped from these models, during the stepwise selection process, if their inclusion no longer significantly added to the fit of the model. Selection (and dropping) of variables was made on the basis of likelihood ratio tests, obtained by calling the anova function in lme4 in which the change of deviance between the simpler and more complex model is assessed according to the chi-squared distribution (considered to be a conservative test: Bates 2010). Since the initial habitat classification of riparian, floodplain, dune and gibber and site selection had been partly based on the distribution of Coolibahs within a general Site area, the influence of Coolibah in multiple regression models containing a habitat term was found to be weak and sometimes not significant. Therefore, alternative models made to retain Coolibah as a significant term, dropping habitat, were developed using the stepwise selection procedures described above. To give a concrete (albeit misguided) idea of the overall fit of REML models, the equivalent terms were fitted in an ordinary least-squares multiple regression model, i.e. without random effects, to generate the customary adjusted variance (R^2) value.

Multivariate Analyses of Transect Landbird Data

Objective classifications of each subsite by Year observation, based on compositional differences, were undertaken using the UPGMA clustering algorithm in PATN (Belbin 1995). The resulting dendrogram was visually assessed for major grouping patterns. The bird species most strongly associated with these groups were identified using Indicator Species Analysis (ISA: Dufrêne & Legendre 1997) implemented in R in the package 'labdsv' (Roberts 2015). Ordination analyses were performed using the SSH routine in PATN to visualise the groupings identified. The response data table comprised 150 observations (subsite visits) of all bird species recorded more than once, using log-transformed density data. ISA analyses were also performed on the *a priori* partitions of Habitat (four groups shown in Table 2), ManagZone (four groups, with 'Eyre' and 'Other' combined), and Year (three groups).

Unconstrained ordinations (NMDS) were examined first, despite the multiple spatial and temporal dependencies, again to identify the strongest patterns in the bird assemblage data at the habitat spatial scale. Principal Correlation Analysis (PCC: Belbin 1995) was undertaken to identify the bird species most strongly associated with the resulting ordination – 1000 randomisations were used to assess the strength of the associations, with only species having a nominal P value < 0.01 selected as indicator species and plotted on ordination graphs. Preliminary unconstrained ordination and PCC analyses of each year's data were undertaken separately to check that any major patterns evident in a single year were not lost when combining all observations (further details below).

Limited hypothesis testing was carried out with constrained, distance-based, anova ('adonis'' in vegan) and direct-gradient ordinations in the R package 'vegan' using the routine 'capscale' (Oksanen *et al.* 2011; based on the permutation methods of Anderson 2001; McArdle & Anderson 2001; Anderson & Willis 2003). Bray-Curtis distances were used, and the factor variables Year, ManageZone and Habitat (groups as above) were specified as the predictor variables, in isolation and all combinations, and the most parsimonious model was selected based on alpha = 0.01 criterion (from 999 randomisations). These tests are equivalent to linear models in regression, i.e. all predictor variables are treated as fixed effects (Zuur *et al.* 2009), and so a conservative P value was adopted, given the multiple dependencies in the data. The results were compared with a more complex model, specifying Sites as a 'strata' variable (equivalent to specifying Sites as a random effect, such that randomisations of subsite observations only occurred within Sites – see Oksanen *et al.* 2011). To guard against the possibility that significant results reflected heterogeneity of multivariate variance rather than actual differences in mean assemblage composition (Warton *et al.* 2012), a test of multivariate dispersion at the finest spatial scale, i.e. Habitats, was conducted in vegan (Anderson 2006). Triplots of the first three axes of the resulting constrained ordination were plotted (three graphs of the different pairwise combinations of axes), showing subsites, most influential species and factors.

Influence of Vegetation and Other Habitat Variables on Bird Diversity

The REML models of bird species richness and community abundance in relation to the relative cover of dominant woody plant species and other habitat variables previously described were interpreted to compare effect sizes and direction of plants and other habitat variables that significantly contributed to diversity and abundance. Given the tight relationship between richness and abundance, and consequent similarities in models of richness and abundance, a separate REML model of the square root of bird abundance was built stepwise, after including the square root of species richness. Although the main measure used to assess avian alpha diversity was species richness (and its transformations), the relationships between various measures of diversity and evenness – Shannon-Weaver H', Pielou's J, Simpson's measures of diversity (D_2) and evenness (E_D), Heip's simplified evenness (E_{H2}), as reviewed by Heip *et al.* (1998) and Magurran (2004) – and individual habitat variables were also simply assessed by correlation analysis, without accounting for hierarchical and other dependencies in the data.

The relationships between vegetation and bird assemblage composition were examined using multivariate statistics. Initially each year's bird data were *q*-mode ordinated (SSH NMDS in PATN) after removing singleton sites and species from the data table, i.e. respectively, censuses with density estimates for only one species and species for which only one density estimate was obtained. This is recommended practice in multivariate analysis (Belbin 1991), as removal of singletons and infrequent species generally leads to clearer patterns being evident in ordination space. Principal axis correlation analysis of plant species and other habitat variables were then undertaken *post-hoc* to determine the multiple correlation coefficient of the relationship between each habitat variable in turn and the arrangement of subsites in ordination space. Monte Carlo permutation procedures (MCAO routine in PATN; 1000 randomisations) were used to test the significance of these relationships. This series of steps is an example of indirect gradient analysis since the bird distribution and abundance data solely inform the ordination solution, in contrast with direct gradient analysis in which the ordination axes are constrained to be functions of the predictor variables (ter Braak 1986). Enumeration of the species and subsites removed from each year's data prior to ordination is presented in the Results. The data were then recompiled across all years and subject to SSH NMDS ordination in PATN (again with removal of singletons). For any subsite having multiple observations, i.e. replicate counts across years, its mean position in ordination space was calculated, and this simplified solution was used to assess the influence of plant species and other habitat variables on the spatial patterning in the bird data, as described above (PCC & MCAO analyses).

Based on the results of the foregoing analyses and taking note of the plant and habitat variables which had strong relationships with bird assemblage composition, and also which variables showed divergent relationships (vectors aligned with different parts of ordination space), judicious selection of a few plant and habitat variables was made for inclusion in a direct gradient analysis, using the routines capscale and cca in vegan (Oksanen *et al.* 2011). Since some of the plant and other habitat variables may vary systematically with longitudinal position in the river system, and certainly vary according to habitat, solutions with or without the factors Year, ManageZone and Habitat were trialled. Again a conservative P value (< 0.01) was adopted for the randomisation tests of significance for inclusion of each plant and habitat variable in the final model. The dominant tree in the region, Coolibah, was entered first in each sequence of model building as it was expected to have most influence on the distribution of birds among assemblages in the region. Triplots showing the influential and frequently-recorded bird species, retained independent variables, and the position of subsites in the constrained ordination were plotted for visual interpretation.

3 Results

Across the three years of survey 152 bird species were recorded (Appendix 1) of which 146 species were recorded at sites. The six not detected at sites included some notable species. Black-breasted Buzzard is classified as Rare in South Australia, and one bird was seen soaring over the Cowarie airstrip towards the end of the third fieldtrip, after the heavy rainfall event. Grey Falcon, Vulnerable nationally (Garnett *et al.* 2011) and Rare in South Australia, and classified as Endangered in the Outback Region by Gillam & Urban (2013), was seen in April 2015 on Cowarie Station where it is regularly recorded. A flock of 24 Cattle Egrets was seen near the Birdsville Track on the northern parts of Cowarie Station on 5 May 2015; both the locality and habitat (dry gibber plain – see Figure 2) were highly unusual for this self-introduced species (Marchant & Higgins 1990). Several Gibberbirds and small flocks of Inland Dotterel were seen while driving along the Birdsville Track and between sites in gibber habitat at various times. Two Banded Whiteface were seen in swampy gibber habitat, and photographs taken, while driving north from Cowarie Crossing on 3 May 2015. Immediately prior to the third fieldtrip Mark McLaren had photographed a Crested Bellbird in sand dune habitat to the south of the Warburton River on Kalamurina. This species is uncommon in the Far North East (Reid *et al.* 1990) to rare in these parts of the Outback Region (Gillam & Urban 2013). It was not recorded in the Coongie Lakes region by Reid & Gillen (1988), nor along Cooper Creek in 2012 (Reid & Gillen 2013), but the species appeared to be not uncommon in the Lower Cooper Creek region in the early-mid 1980s (e.g. Reid 1984; Badman 1989), and there is a historical record from the Diamantina Zone by Reese (1930). The species' current status in the study area warrants closer attention given its severe decline in many agricultural regions in southern South Australia and across south-eastern Australia generally (Reid 1999).

Figure 2 Cattle Egrets on a station track south of Mt Gason in May 2015 **Suzi Bond**

The total of 152 species is a relatively small figure for three years of intensive survey in a large region, and probably partly reflected the very dry conditions that prevailed throughout the area from prior to the project's commencement to midway through the third survey when the drought broke. During a ten-month survey of a much smaller area around the Coongie Lakes region in 1987, Reid & Gillen (1988) recorded 161 species (and an extra eight species in the wider region which included the Koonchera Waterhole area). Badman (1989) recorded 160 species across multiple trips to the length of Cooper Creek in South Australia over 10 years in the 1970s and 80s. The greatest difference between the present study and those of the Cooper Creek region was the greater diversity of waterbirds in the earlier studies. Only 54 species of waterbirds were recorded in the present study, compared with 61 (of 161) species in the Coongie Lakes study and 62 species in Badman's study, and so the number of landbird species recorded in each of these studies was remarkably similar. The current study's annual totals of 112 to 123 species are also fewer than the total recorded on the comparable once-off survey of Cooper Creek in 2012 by Reid & Gillen (2013: 140 species, including 44 waterbird species); again, the discrepancy is mainly explained by greater waterbird diversity in the earlier study. Passerines (54 of 152 species) comprised just over a third of the species in the present study, and several groups prominent in higher rainfall parts of Australia were poorly represented. No thornbill (*Acanthiza*) species were recorded, although two species of whiteface (*Aphelocephala*, a related arid-zone group in the Family Acanthizidae) were present, and only nine species of honeyeater (Meliphagidae), including three chats, were observed.

Two species of national conservation significance (Garnett *et al.* 2011) were recorded at sites, Curlew Sandpiper and Painted Honeyeater, both Vulnerable, although the sandpiper has had its conservation status recently upgraded to Critically Endangered under the *EPBC Act, 1999* [http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=856], due to drastic reductions in the global population over the past 20 years. One Curlew Sandpiper was seen on a large shallow lake south of Tinnie Landing, Kalamurina, in late April 2016. One or two Painted Honeyeaters were seen at Stony Point Waterhole, Cowarie, and at Clifton Hills Outstation in May 2015. Two nationally Endangered species, Plains-wanderer and Australian Painted Snipe, are known to occur in the study area, and a Plains-wanderer was possibly seen at night as we drove into the camp at Kalamunkinna Waterhole, Cowarie, in May 2014. The species was seen by the senior author near Ultoomurra Waterhole, Clifton Hills, in June 2000, and there is a recent specimen record from near Mirra Mitta Bore, Cowarie (mapped in Garnett *et al.* 2011). The Australian Painted Snipe has bred in the Diamantina Channel Country wetlands in Queensland (Jaensch 2003), and the species bred on Goyder Lagoon (Pandiburra Bore-Koonchera district) in 2000/01 (Reid & Jaensch 2004).

Several remarkable sightings of birds outside their customary range were made, most during the second survey. The Spotted Bowerbird was thought to be extinct in South Australia, the species having been hunted to extinction from the Murray Riverlands district early in the twentieth century (Parker & Reid 1979). One bird was seen briefly at the 'D-Split' waterhole, Diamantina River, on the southern end of Pandie Pandie Station on 12 May 2015. Parker (1979) and Reid (2000) discussed an early historical sighting of a bowerbird that was probably this species documented by Sturt (1849) from an unknown location on the Eyre Creek near the Queensland-South Australian border. The current observation extends its documented distribution about 200 km southwards from Cluny Homestead in Queensland (Parker 1979). Observations of single birds of Olive-backed Oriole (Bond & Reid 2016) at Double Bluff Waterhole and a female Golden Whistler at D-Split waterhole (both on Pandie Pandie Station) in May 2015 may have been of birds on their autumnal northwards migration, but displaced much further west than usual. Several Tawny Grassbirds were seen and heard around Burt's Waterhole, Clifton Hills, in May 2015 (Reid 2016), inhabiting dense, 'greened-up' low floodplain herbage following limited flooding over this north-eastern portion of Goyder Lagoon. This species has been recorded in the wider Lake Eyre Basin and Channel Country region (Jaensch *et al.* 2013) only in the past few years, with the exception of an earlier historical specimen record from Nappa Merrie Station (dating from the mid-1970s), and until recently was thought to be restricted to higher-rainfall parts of northern and eastern Australia.

There are two range-restricted species of birds endemic to the Lake Eyre Basin (including the Bulloo River), the Eyrean Grasswren and Grey Grasswren, and both were seen sparingly at or around a few sites during the three surveys. The subspecies of Grey Grasswren that occurs in the study area, *Amytornis barbatus diamantina*, is restricted to the lower portions of the Georgina-Diamantina River Catchment, which in South Australia includes Goyder Lagoon south to the Kalamunkinna Waterhole area. The Eyrean Grasswren is restricted to sandhill canegrass habitats in the Simpson and Strzelecki Deserts and intervening dunes in the Sturts Stony Desert region, such as Koonchera Dune.

Other species recorded which have significance with respect to distribution and biogeography and/or conservation in South Australia, were Brown Quail, Freckled Duck, Flock Bronzewing, Red-tailed Black-Cockatoo, Red-rumped Parrot, Channel-billed Cuckoo, Black-eared Cuckoo, White-browed Babbler and Restless Flycatcher. These species will be considered in the Discussion.

3.1 Bird Diversity by Site and Year

The numbers of species observed at sites varied slightly from one survey to the next – 112 in 2014, 216 in 2015 and 123 in 2016 – with a large proportion seen on all three surveys (86 species) and relatively few species restricted to one year (Figure 3). Three species, namely White-plumed Honeyeater, Australian Raven, and Willie Wagtail, were ubiquitous being recorded at all sites on every trip, while 48 species were widespread being detected at 20 or more of the 43 site visits (Appendix 1). A majority of bird species (85) were detected on 10 or fewer visits to sites (Figure 4).

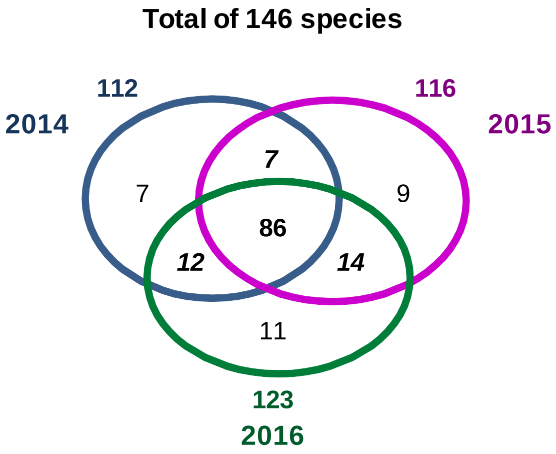


Figure 3 Venn diagram showing turnover of 146 bird species over the three surveys

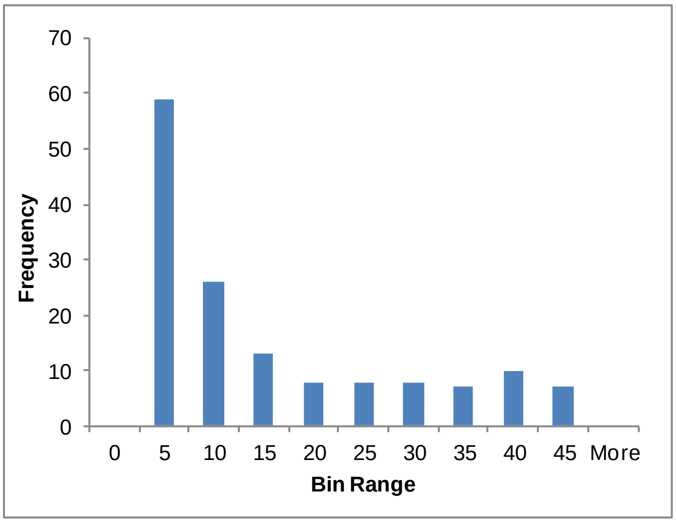


Figure 4 Frequency histogram of number of site visits at which 146 bird species were recorded over the three surveys (total of 43 site visits)

Of the 146 bird species detected during at least one site visit, 49 (33.6%) were wetland-dependent non-passerine waterbirds (waterfowl, or cormorants, herons, ibis and allies, or rails, terns, shorebirds and allies). If we combine the Mona Downs and Kuncherinna Waterhole sites, and with the 23 sites distributed among the four management zones (and the Tippipilla Creek site in 'Other'), at sites in the Goyder Lagoon zone waterbirds make up a significantly larger proportion of avian assemblages: at the average site waterbirds made up 29% of all species, more than double that (14%) at both the average Diamantina and Warburton-Kallakoopah site (Table 5; Figure 5). Because Goyder Lagoon assemblages were also generally more species rich, in fact the mean number of waterbird species at an average Goyder Lagoon site visit (16.6) was almost three times as great as in the other zones (6.6 at Diamantina, 5.8 at Warburton-Kallakoopah). Koonchera Waterhole (means of 37.25% by proportionate composition and 24.7 waterbird species per visit) and the artificially inundated Tepamimi Waterhole (38.80%, 21.5 species) and Goyder Lagoon Waterhole (46.74%, 19.0 species) had the highest dominance of waterbirds among the 23 sites. Excluding Tepamimi and Tippipilla, analysis of variance of mean site richness and percentage richness among the three main management zones, revealed that while total bird species richness and waterbird richness and dominance were significantly greater at sites in Goyder Lagoon than in the other two zones, the number of landbird species among zones did not differ significantly (Table 5), i.e. the greater richness of bird communities across Goyder Lagoon was driven by the waterbird component. Neither the proportions nor absolute numbers of waterbird and landbird species differed significantly between the Diamantina and Warburton-Kallakoopah zones.

With respect to changes in landbird and waterbird species richness and proportions over time, quite different results were obtained to those reported for management zones. There was a steady increase in the mean number of landbird species (and all bird species) in successive years (Table 6). Approximately six more landbird species were recorded across sites in 2015 and 2016 than in the previous year. This occurred despite a deepening of drought conditions (in terms of rainfall deficit) in 2015 compared with 2014, and so it is likely that the freshwater flows which had refreshed most areas surveyed in 2015 were responsible for attracting additional landbirds to habitats bordering rivers. An extra two waterbird species were seen on average in 2015 and 2016 (*ca* 10 species per site) than in 2014 (eight waterbird species; Table 6), but these were not significant differences.

One way anova of site-level bird species richness by property identity revealed that richness did not vary significantly between properties for all bird species combined and for all landbirds (both $P > 0.05$), but that waterbirds were much more speciose at Clifton Hills sites than on the other three properties ($P < 0.01$; tests performed on log-transformed data).

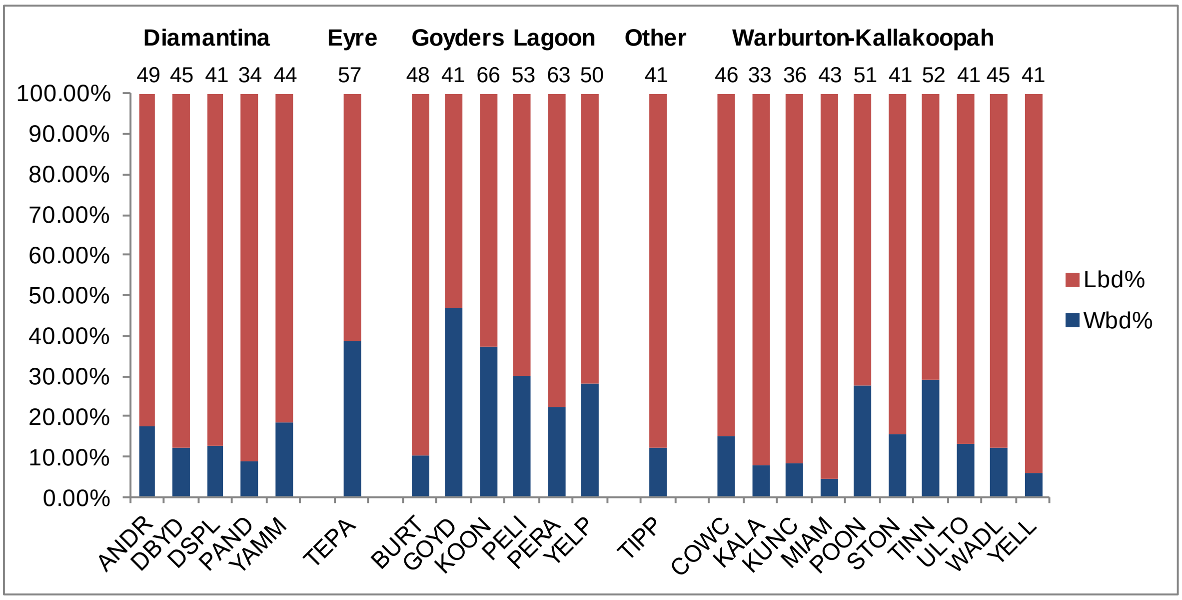


Figure 5 Column chart of proportions of the number of waterbird (Wbd) and landbird (Lbd) species averaged across visits (one to three) at 23 sites (Mona Downs and Kuncherinna sites combined), grouped by management zone. The actual or mean number of all bird species recorded at sites is shown at the top of each column

Table 5 Variations in proportionate and actual numbers (means +/- se) of all, waterbird and landbird species at sites across management zones.

Data were averaged at sites where multiple visits occurred before undertaking one-way analysis of variance

Management Zone	**Percent Waterbird Spp**	**# All Bird Spp**	**# All Waterbird Spp**	**# All Landbird Spp**
Diamantina (n = 5)	13.83% +/- 1.76%	42.4 +/- 2.46	6.1 +/- 1.08	36.3 +/- 1.59
Goyder Lagoon (n = 6)	29.14% +/- 5.09%	53.5 +/- 3.85	15.4 +/- 2.65	38.1 +/- 3.73
Warburton-Kallakoopah (n = 10)	13.88% +/- 2.66%	42.8 +/- 1.93	6.5 +/- 1.48	36.3 +/- 1.05
$F_{2,18}$	6.09	4.55*	5.21*	0.04*
P	<0.01	<0.05	<0.05	*n.s.*

* tests performed on log-transformed data

Table 6 Variations in proportionate and actual numbers (means +/- se) of all, waterbird and landbird species at sites between years. One-way analysis of variance results are shown

Year	**Percent Waterbird Spp**	**# All Bird Spp**	**# All Waterbird Spp**	**# All Landbird Spp**
2014 (n = 15)	17.62% +/- 3.90%	38.3 +/- 2.71	7.7 +/- 2.04	30.6 +/- 1.55
2015 (n = 14)	20.12% +/- 2.85%	46.6 +/- 2.44	9.9 +/- 1.77	36.6 +/- 1.48
2016 (n = 14)	18.03% +/- 2.74%	52.4 +/- 2.83	10.2 +/- 1.95	42.1 +/- 1.51
$F_{2,40}$	0.17	8.66*	2.00*	14.02*
P	*n.s.*	<0.001	*n.s.*	<0.001

* tests performed on log-transformed data

Despite the fact that waterbirds comprised only a third of the avifauna across sites and surveys, they generally occurred at lower frequencies than landbirds, and they were the majority of species that were only detected at sites in a single year. Of these 27 singleton 'year occurrences' (Figure 3), an improbably high number (16) were waterbird species (χ^2_1 = 8.45, P < 0.01), although this tendency was reversed in 2015 when six of the nine singleton occurrences were landbirds, namely Stubble Quail, Spotted Bowerbird, Painted Honeyeater, Golden Whistler, Olive-backed Oriole and Tawny Grassbird, although the last is dependent on rank lush herbage generally associated with wetlands (Reid 2016). Most of these singleton year occurrences were also single site occurrences, and only five species were recorded at two (Little Pied Cormorant in 2014, Painted Honeyeater in 2015, Australian Pratincole in 2016) or more sites in the year they were detected (noting that the pratincole was seen in other years away from sites). The Straw-necked Ibis (at four sites) and Gull-billed Tern (six) became prevalent in 2016 after the heavy rainfall event. A *t*-test (t_{144} = 3.30; P < 0.01, using log-transformed data) confirmed that landbird species occurred more frequently across site visits (mean +/- se = 16.1 +/- 1.46) than waterbirds (8.1 +/- 1.26).

Table 7 Values of the Simple Matching Coefficient (SMC), expressed as percentage similarity, for all between-site visit comparisons and for various subsets of the data by Year, Property and Site, focussing on within-Property comparisons

	SMC	***n***			**SMC**	***n***			**SMC**	***n***
Grand Mean	**44.40%**	**903**		**Between-Year All**				**Between-Year, Within-Site**		
				2014-2015	42.13%	210		Kalamurina	58.59%	2
Within-Year All				**2014-2016**	41.60%	210		Cowarie	51.08%	6
2014	42.36%	105		**2015-2016**	46.88%	196		Clifton Hills	50.86%	12
2015	48.38%	91		**mean**	**43.46%**	**616**		Pandie Pandie	61.38%	4
2016	49.09%	91		**_mean*_**	**_43.06%_**	**_592_**		**mean**	**53.31%**	**24**
mean	**46.40%**	**287**								
				Between-Year, Within-Property				**Between-Year, Within-Site, By Year**		
Within-Year, Within-Property				**2014-2015**				**2014-2015**	52.78%	10
2014				Cowarie	48.40%	16		**2014-2016**	52.64%	7
Kalamurina	55.30%	3		Clifton Hills	40.52%	48		**2015-2016**	54.74%	7
Cowarie	58.11%	6		Pandie Pandie	55.50%	4				
Clifton Hills	36.01%	15		**mean**	**43.25%**	**68**				
Pandie Pandie	51.06%	1		**2014-2016**						
mean	**44.24%**	**25**		Kalamurina	53.97%	12				
2015				Cowarie	47.31%	8				
Cowarie	55.73%	6		Clifton Hills	36.94%	36				
Clifton Hills	47.75%	28		Pandie Pandie	54.75%	4				
Pandie Pandie	67.92%	1		**mean**	**42.92%**	**60**				
mean	**49.69%**	**35**		**2015-2016**						
2016				Cowarie	57.19%	8				
Kalamurina	59.06%	6		Clifton Hills	42.77%	48				
Cowarie	57.14%	1		Pandie Pandie	59.09%	4				
Clifton Hills	46.25%	15		**mean**	**45.78%**	**60**				
Pandie Pandie	62.26%	1								
mean	**50.76%**	**23**								

* average of all values excluding same site comparisons, i.e. those values in the right-hand section of the table

Simple Matching Coefficient (SMC) analyses revealed a third set of notable patterns in how bird assemblages, at the whole of site scale, varied across time and space. Values of the SMC varied from 18.5% (the 2014 visit to Ultoomurra Waterhole compared with the 2016 visit to Koonchera) to 72.2% (the 2014 visits to Cowarie Crossing and Kuncherinna Waterhole). The grand mean of all SMC indices was 44.4% (Table 7), which can be construed as 44% or roughly five in every 11 bird species were shared across any pair of site visits, i.e. there were slightly fewer than half of the pairwise species pool in common.

Table 8 Values of the Simple Matching Coefficient (SMC), expressed as percentage similarity, for all between-site visit comparisons and for various subsets of the data by Year and Property, focussing on between-Property comparisons

	SMC	*n*			SMC	*n*
Within-Year, Between-Property				**Between-Year, Between-Property**		
2014				**2014-2015**		
Kalamurina-Cowarie	54.61%	12		Kalamurina-Cowarie	50.82%	12
Kalamurina-Clifton Hills	38.58%	16		Kalamurina-Clifton Hills	41.64%	24
Kalamurina-Pandie	44.31%	6		Kalamurina-Pandie	47.03%	6
Cowarie-Clifton Hills	37.00%	24		Cowarie-Clifton Hills	37.95%	56
Cowarie-Pandie	44.47%	8		Cowarie-Pandie	43.58%	16
Clifton Hills-Pandie	39.73%	12		Clifton Hills-Pandie	42.60%	28
mean	**41.78%**	**78**		**mean**	**41.60%**	**142**
2015				**2014-2016**		
Cowarie-Clifton Hills	44.50%	32		Kalamurina-Cowarie	50.15%	22
Cowarie-Pandie	48.85%	8		Kalamurina-Clifton Hills	40.37%	42
Clifton Hills-Pandie	51.44%	16		Kalamurina-Pandie	45.86%	14
mean	**47.10%**	**56**		Cowarie-Clifton Hills	35.68%	36
2016				Cowarie-Pandie	44.31%	12
Kalamurina-Cowarie	56.64%	8		Clifton Hills-Pandie	37.69%	24
Kalamurina-Clifton Hills	45.35%	24		**mean**	**41.08%**	**150**
Kalamurina-Pandie	46.26%	12		**2015-2016**		
Cowarie-Clifton Hills	47.37%	12		Kalamurina-Cowarie	53.87%	16
Cowarie-Pandie	55.05%	4		Kalamurina-Clifton Hills	47.85%	32
Clifton Hills-Pandie	46.26%	12		Kalamurina-Pandie	51.14%	8
mean	**47.78%**	**72**		Cowarie-Clifton Hills	43.37%	40
				Cowarie-Pandie	49.38%	12
				Clifton Hills-Pandie	46.84%	28
				mean	**47.36%**	**136**

This discrepancy (greater variation in composition between sites) was largest in 2014 (42.4%) while, in 2015 (48.4%) and 2016 (49.1%), any pair of sites had close to half their species in common, i.e. the avifauna had homogenised to a degree in the last two surveys. In 24 instances, pairs of visits to the same site could be compared and the mean SMC of 53.3% (Table 7), meant that just over half of the species seen on one visit to a site could be expected to be seen on a second visit in a different year. There was no evidence of a uniform directional change in assemblage composition across the three surveys. There were as many species shared among any pair of sites when comparing 2014 and 2015 surveys (42.1%) or 2014 and 2016 surveys (41.6%), while site assemblages were more similar between 2015 and 2016 (46.9%).

The mean of all between-year comparisons (excluding multiple visits to an individual site across years) was 43.1%. Comparing this to the earlier figure for same site similarity, 53.3%, meant that an additional four of five species in common could be expected when revisiting a site surveyed in a different year than when visiting different sites across years. However, most of this difference was caused by the pronounced variation in assemblage composition between sites on Clifton Hills. Excluding Clifton Hills sites, the average between-year within-property similarity in composition was 53.7%, compared with 40.1% for Clifton Hills sites between-year comparisons. It can be seen from Table 7 that there was a consistent trend for Clifton Hills sites to have more markedly different bird communities than the other three properties, and this no doubt reflects the fact that this enormous station has both Diamantina and Warburton river frontages (as well as all of Goyder Lagoon), whereas the other three properties – at least the portions to which we had access – have either Diamantina or Warburton river frontages. Similar patterns are evident when examining within-property within-year compositional similarities – Clifton Hills sites in any one year ranged from 8% to 22% lower values of the SMC than the other three properties (Table 7).

Cluster analysis of the 43 site visits (waterbirds and landbirds included but with singleton species removed) revealed two main divisions in the compositional assemblage data (Figure 6). The first division separated Goyder Lagoon sites (Group 3) from Diamantina (Group 2) and Warburton-Kallakoopah (Group 1) sites. The Tippipilla Creek sample and both visits to Tepamimi Waterhole (Eyre) clustered with the Goyder Lagoon group, and the only 'ring-in' from other zones was the 2016 visit to Andrewilla. The second division in the dendrogram separated Diamantina sites from the Warburton and Kallakoopah sites (Figure 6). All 20 sites assigned *a priori* to the Warburton-Kallakoopah management zone grouped together truly; such coherence is rare in ecology. The Burt's Waterhole sample (*a priori* assigned to the Goyder Lagoon management zone) was placed in the Diamantina cluster, but part from this and ANDR16's placement, the groups recovered from the cluster analysis were a near-perfect match for the project team's *a priori* geographic regionalisation of the study area. It is also noteworthy that longitudinal positioning of the three main management zones was not reflected in sister relationships in the dendrogram. Sites in the well-channelised parts of the system (Diamantina and Warburton rivers) were more similar in avifaunal composition than either was to Goyder Lagoon assemblages. Finally, in only three cases did pairs (Yammakira, Double Bluff) or triplets (Koonchera) of sites have the greatest faunal similarity (i.e. cluster together as each other's closest neighbours), i.e. the similarity in bird assemblages within years (within a management zone) generally exerted more influence on community composition than did site identity.

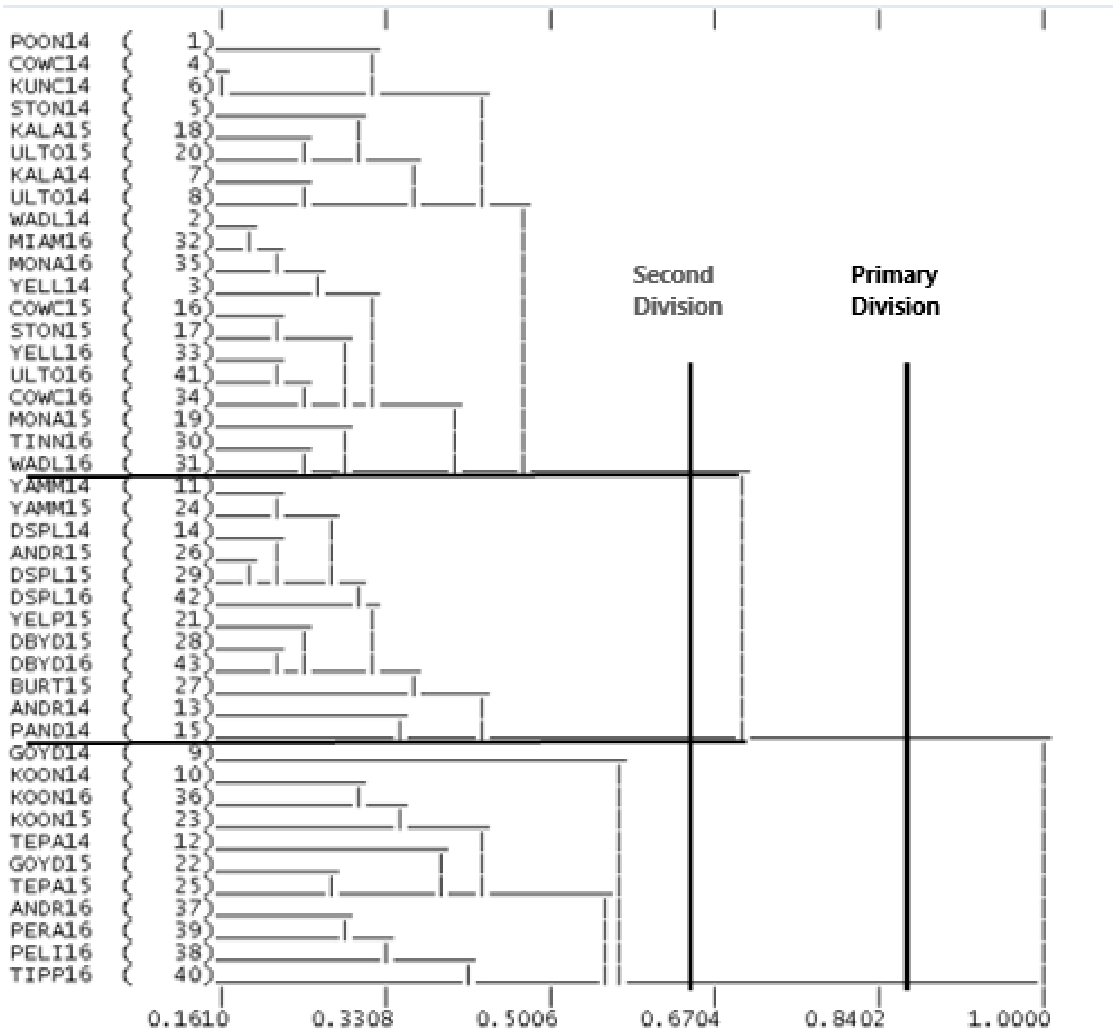


Figure 6 UPGMA dendrogram of 43 site visits, with two partitions and three main groups shown

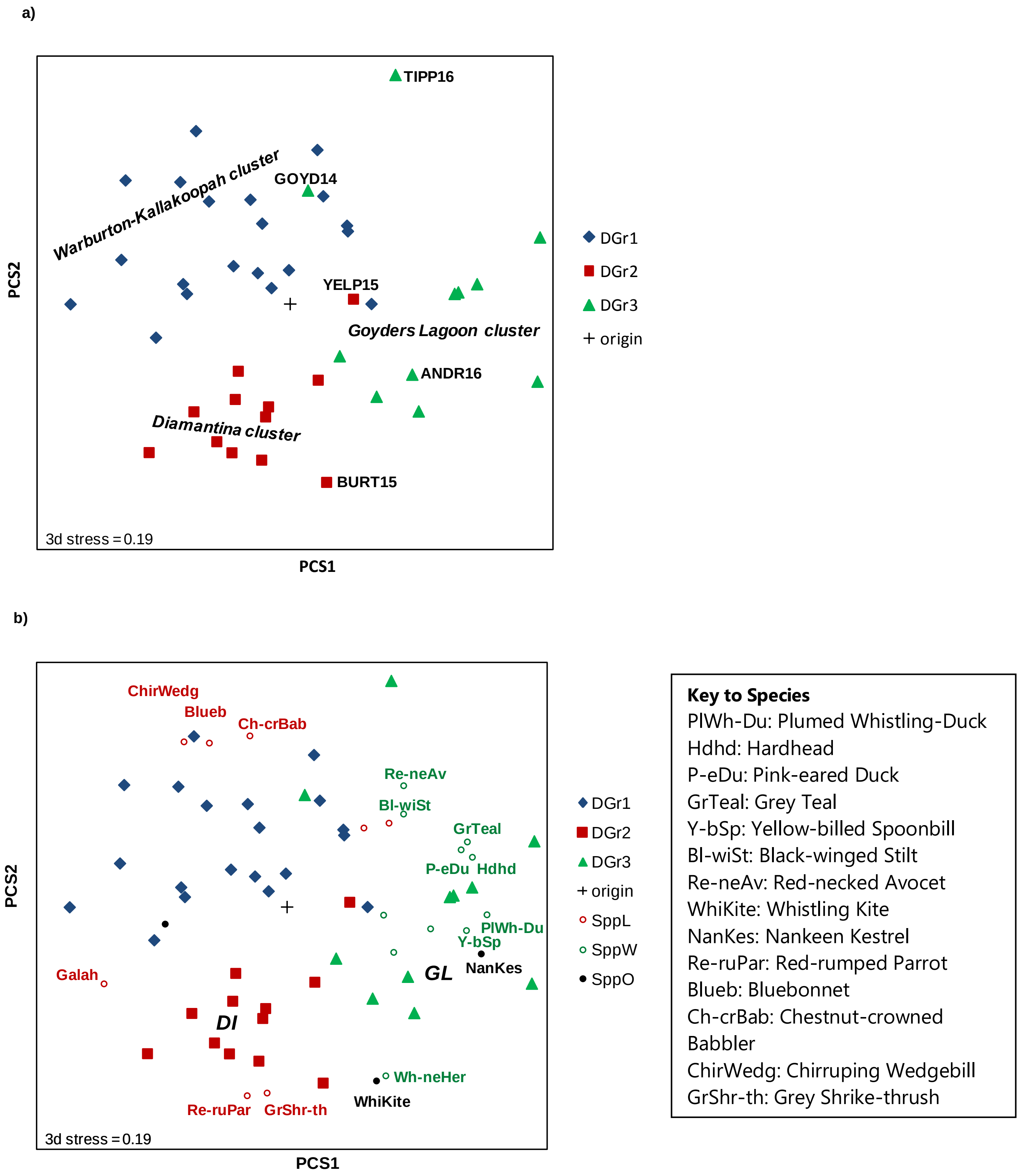


Figure 7 First two axes of a rotated three-dimensional NMDS ordination of 43 site-visit assemblages, showing a) the main clusters and identities of anomalous or outlier samples, and b) identities of species most strongly correlated with solution (Rm > 0.6, from PCC analyses)

Ordination of the 43 site visits revealed similar patterns to the cluster analysis, with the major axis of variation aligned with the first axis (PCS1 – axis 1 of the three-dimensional NMDS solution rotated to principal components), placing the Goyder Lagoon cluster at the right-hand end and the Diamantina and Warburton clusters placed at the left-hand end in Figure 7, and with site visits to these two zones separated on the second ordination axis. Some of the species responsible for site placement are shown in Figure 7b. A large bunch of waterbird species were closely associated with the Goyder Lagoon cluster, most strongly the ducks, Plumed Whistling-Duck, Hardead, Pink-eared Duck and Grey Teal, and the large wading bird, Yellow-billed Spoonbill. Black-winged Stilt and Red-necked Avocet are also aligned with Goyder Lagoon sites but also have an affinity with some Warburton-Kallakoopah sites reflecting their known habitat preference, at times, for saline wetlands (Marchant & Higgins 1993), and so their obliquely-angled placement reflects these combined zone preferences. Five dryland birds were largely responsible for discriminating between Diamantina and Warburton-Kallakoopah assemblages, with Red-rumped Parrot and Grey Shrike-thrush characteristic of northern sites, and Bluebonnet, Chestnut-crowned Babbler and Chirruping Wedgebill largely restricted to sites downstream of Goyder Lagoon. In 2014, the hyper-saline waterholes of the Warburton River were largely devoid of kites, although they (Whistling Kite and Black Kite) returned in subsequent years after waterholes were refreshed from local runoff events. However, the greater frequency of occurrence of Whistling Kites at sites in Goyder Lagoon and along the Diamantina River was sufficient for it to be recognised as a highly influential species (R_m = 0.74 in PCC analyses; $P < 0.001$), with its vector, along with White-necked Heron, arrowed obliquely to the lower right portion of the plot (Figure 7b). The Nankeen Kestrel was most frequently observed around Goyder Lagoon sites while the Galah, otherwise widespread in the region along the major rivers, was absent from several Goyder Lagoon assemblages. Of the 23 most influential species (R_m > 0.6 in PCC analyses), 1000 randomisations tests indicated permuted significance of $P < 0.001$ for all but Nankeen Kestrel (R_m = 0.68; $P = 0.002$). Two other species prevalent in Goyder Lagoon were Pacific Black Duck and Little Grassbird. A few species had their strongest influence on the third ordination axis (not shown here), and these trends may partly reflect temporal changes in assemblage composition over the three years. For instance the nomadic landbirds, Crimson Chat and Masked Woodswallow, were more frequent in 2016, particularly following the rainfall event.

Many of the foregoing results were confirmed by anosim tests. First, year of survey had a highly significant influence on assemblage composition (R_A = 0.174; $P = 0.001$), confirming earlier analyses that the identities of birds detected in the study area as a whole and at individual sites changed substantially from one survey to the next. This test can be regarded as virtually free of any dependencies in the data that might inviolate the assumptions of the test, given that most sites were widely spaced apart (minimising the likelihood of spatial autocorrelation effects). However, the results of anosim tests of the effect of ManagZone (R_A = 0.584; $P = 0.001$) and Property (R_A = 0.080; $P = 0.136$, *n.s.*) on assemblage composition, while heavily supporting one hypothesis (management zone) and rejecting the other (property identity), could potentially be affected by temporal autocorrelation issues given repeat visits to six sites in two or three years. However, cluster analysis (above) showed that temporal dependencies at the site level seem minor, and so these results are thought to provide solid evidence for the very strong structuring force of the geomorphological regionalisation (management zones) on bird community assembly in terms of species composition. An anosim test on a subset of the data (comprising 11 observations per year), after randomly selecting one visit only from sites where multiple surveys occurred, and restricting permutations such that site visits were shuffled within years only (and so free of any potential temporal dependency), returned very similar results for the factors, ManagZone (R_A = 0.542; $P = 0.001$) and Property (R_A = 0.038; $P = 0.255$, *n.s.*).

Table 9 Permutation and distance-based analysis of variance of the survey design factors, year of survey (Year) and management zone (MZU) on site assemblage composition. Sørensen distance on presence-absence data used in adonis routine. Probabilities derived from 999 randomisations

Factor	Df	SumsOfSqs	MeanSqs	*F*.Model	R^2	Pr(>*F*)
MGU	3	1.119	0.373	7.730	0.328	0.001
Year	2	0.418	0.209	4.332	0.123	0.001
MGU.Year	5	0.331	0.066	1.372	0.097	0.069
Residuals	32	1.544	0.048		0.452	
Total	42	3.413			1.000	

Direct gradient ordination analyses (cca) also confirmed the significant influences of Year and ManagZone, in combination, on bird assemblage composition. With all species and site visits retained, both factors were highly significant (P = 0.001). The interaction term, ManagZone.Year, was also significant (P = 0.013). After removal of 31 infrequently recorded species, similar results were obtained (cca; Year and ManagZone, both P = 0.001; interaction, ManagZone.Year, P = 0.050), but with the interaction now marginally significant. A formal, non-parametric, distance based analysis of variance (Anderson 2001) performed in 'adonis' (vegan) on all the data (43 site visits by 146 species, Sørensen distance) suggested the interaction term was not significant (P = 0.069), while confirming the strength of the main effects, Year and ManagZone (both P = 0.001) – see Table 9. The results of the distance-based analyses (with their use of the ecologically realistic distance metrics, Sørensen and Bray-Curtis indices), are probably more robust than those from the eigenvector methods used in correspondence analysis (Faith *et al.* 1987).

3.2 Landbird Diversity and Abundance

Including the replicate observations at Cowarie Crossing and Andrewilla Waterhole in 2016, a total of 150 transect counts was gathered by J. Reid across the entire survey. Among these were 83 unique subsites across the 24 sites. Analyses presented here are based on 142 unique combinations of subsite and year of survey. Density estimates were derived for 77 species of landbird, and ranged from 0.1 birds ha^{-1} (many species) to 26.2 birds ha^{-1} for Zebra Finches on a sand dune transect at Tinnie Landing, Kalamurina, in 2016. Generally landbird richness and total abundance were greatest at riparian sites and in the third year of survey (Table 10). Across the three years of survey the number of species in riparian habitats exceeded numbers in other habitats by about eight species per transect count, and their abundance was about double that of the other habitats (Table 10). Abundance of landbirds in dunefield habitat was generally lower than that in floodplain habitat in 2014, but averaged greater in 2015 and 2016, and bird numbers in dunes rose more than fivefold over the three years, although most of this increase was due to large flocks of Zebra Finches at a few dune sites in 2016. Increases in landbird abundance at floodplain and riparian sites were more modest over time, with numbers in 2016 about double those in 2014 and 2015 (Table 10). Species richness of landbirds in dunes in 2016 (13.8 species per count) was approximately double the number of species in 2014 (6.0) and 2015 (6.7). Changes in species richness in the other habitat were not as dramatic, but still substantial (six species more in 2016 than 2015 in riparian habitat, and 4.5 species more in 2016 than 2015 on the floodplain). Richness and abundance in the few gibber samples were uniformly low, averaging just over two species per transect and 0.3 birds ha^{-1}. The species observed in gibber habitat were Australian Hobby, White-plumed Honeyeater, Willie Wagtail, Zebra Finch, White-backed Swallow, Fairy Martin and Australasian Pipit.

Table 10 Summary statistics for landbird community abundance (summed densities of all species per ha), species richness, and their ratio (Ab/Rich) by year of survey and major habitat. Habitats: Riparian (Rip), Floodplain (Fld) and Dune (Dun); the few gibber samples are not shown

Abundance	**2014**			**2015**			**2016**			**All Years**		
	Rip	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**
n	*20*	*15*	*7*	*21*	*20*	*10*	*20*	*16*	*9*	***61***	***51***	***26***
min	4.3	0.1	1.1	2.0	0.2	0.7	9.0	2.3	2.7	**2.0**	**0.1**	**0.7**
max	18.0	16.5	5.2	29.5	14.5	22.2	41.8	26.7	31.3	**41.8**	**26.7**	**31.3**
mean	10.67	4.27	2.91	11.48	4.18	5.68	21.64	10.01	14.18	**14.54**	**6.03**	**7.88**
sd	3.58	3.96	1.58	6.72	4.03	6.28	8.18	7.61	10.49	**8.08**	**5.94**	**8.55**
se	0.80	1.02	0.60	1.47	0.90	1.99	1.83	1.90	3.50	**1.03**	**0.83**	**1.68**

Richness	2014			2015			2016			All Years		
	Rip	Fld	Dun	Rip	Fld	Dun	Rip	Fld	Dun	Rip	Fld	Dun
min	8	1	4	5	1	3	13	6	7	**5**	**1**	**3**
max	23	23	9	23	17	14	27	19	20	**27**	**23**	**20**
mean	16.65	9.07	6.00	14.10	7.60	6.70	20.35	12.19	13.78	**16.98**	**9.47**	**8.96**
sd	4.72	5.40	1.83	4.96	3.83	3.68	4.23	4.35	4.49	**5.26**	**4.82**	**5.00**
se	1.05	1.40	0.69	1.08	0.86	1.16	0.95	1.09	1.50	**0.67**	**0.68**	**0.98**
Ab/Rich	0.64	0.47	0.49	0.81	0.55	0.85	1.06	0.82	1.03	**0.86**	**0.64**	**0.88**

The relationship between community abundance and species richness varied between habitats and over time (Table 10). Expressed as the ratio, Abundance/Richness (mean density per unit species), the species in riparian bird communities occurred at slightly greater abundance (0.64 ha^{-1}) than those in floodplain and dune communities (both < 0.5) in 2014, and these values increased steadily in 2015 and again in 2016, with dune bird communities (0.85) having a slightly greater mean ratio in 2015 than riparian communities (0.81). In 2016 the ratio in both these habitats averaged slightly greater than unity, and greater than floodplain bird communities (0.82). However, these coarse comparisons from the mean data in Table 10 mask some striking trends across habitats and time, and examination of diversity and evenness indices (Table 11) revealed that the increase in mean abundance through time resulted from large increases in a few species more than a steady small increase in most species. As a result communities became less even through time as shown by the decline in the evenness indices (greater dominance of a few species) from 2014 to 2015 and particularly in 2016. Despite species richness declining slightly in the riparian and floodplain habitats from 2014 to 2015, as did the diversity indices, the mean abundance per species increased slightly. This slight increase in mean species' abundances was reflected in lower measures of evenness in riparian habitats but not consistently in floodplain habitats. As noted above, dune bird communities steadily increased in richness and abundance across the three years of survey, as did the mean abundance per species (Abun/Rich), and most diversity indices also steadily increased. However, the evenness of dune bird communities increased (Simpson's and Heip's measures) or remained steady (Pielou *E*) between 2014 and 2015, before uniformly plummeting in 2016 as a few species became much more abundant causing lower equitability among species' abundances. REML modelling of these diversity indices revealed a significant habitat x Year interaction effect for three of the indices, namely Simpson *D*2, Simpson *E* and Heip *E*2 (Site and Site/subsite as random effects; $P < 0.05$). We conclude there are subtle differences in the assembly of bird communities in these three broad habitats over time, presumably in response to the spatio-temporal variations in the distribution of food resources.

Table 11 Diversity and evenness indices for landbird communities averaged across the three main habitats (Riparian: Rip; Floodplain: Fld; Dune: Dun) and year. Mean species richness data are first presented for comparison, followed by the community abundance to richness ratio (Abun/Rich). Three diversity indices are presented, namely Shannon-Weaver (Shannon *H'*), Simpson *D*1 and Simpson *D*2. Three evenness indices are presented, namely Pielou *E*, Simpson *E* (1 – *D*1) and Heip *E*2 (exp(*H'*)/richness)

Variable	2014			2015			2016			All Years		
	Rip	Fld	Dun	Rip	Fld	Dun	Rip	Fld	Dun	Rip	Fld	Dun
Richness	16.65	9.07	6.00	14.10	7.60	6.70	20.35	12.19	13.78	0.84	0.55	0.82
Abun/Rich	0.65	0.42	0.50	0.80	0.48	0.85	1.05	0.76	1.03	0.84	0.55	0.82
Shannon *H'*	2.33	1.71	1.47	1.97	1.60	1.49	2.36	1.91	1.89	2.22	1.73	1.63
Simpson *D*1	0.85	0.73	0.70	0.77	0.72	0.70	0.85	0.79	0.74	0.82	0.74	0.71
Simpson *D*2	7.77	5.08	3.73	5.29	4.54	4.40	7.30	5.31	5.71	6.76	4.94	4.68
Pielou *E*	0.84	0.85	0.84	0.76	0.85	0.84	0.79	0.79	0.74	0.80	0.83	0.80

Variable	2014			2015			2016			All Years		
	Rip	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**	**Rip**	**Fld**	**Dun**
Simpson *E*	0.48	0.62	0.62	0.38	0.64	0.68	0.36	0.48	0.44	0.41	0.59	0.58
Heip *E2*	0.66	0.75	0.76	0.56	0.76	0.78	0.54	0.62	0.57	0.58	0.71	0.70

The broad changes in bird species richness and abundance by habitat and across time are shown in Figure 8. Changes in abundance were generally greater than changes in richness, particularly in the dune communities as outlined above (and see REML results below). Patterns in richness and abundance also varied across the three main management zones surveyed (Figure 9). While richness and abundance in riparian habitats were broadly similar in each zone and uniformly greater than in the other two habitats, floodplain richness and abundance were greater in the Warburton River region than higher up the system, and dunefield richness and abundance were lower in the Diamantina River zone than in regions further downstream.

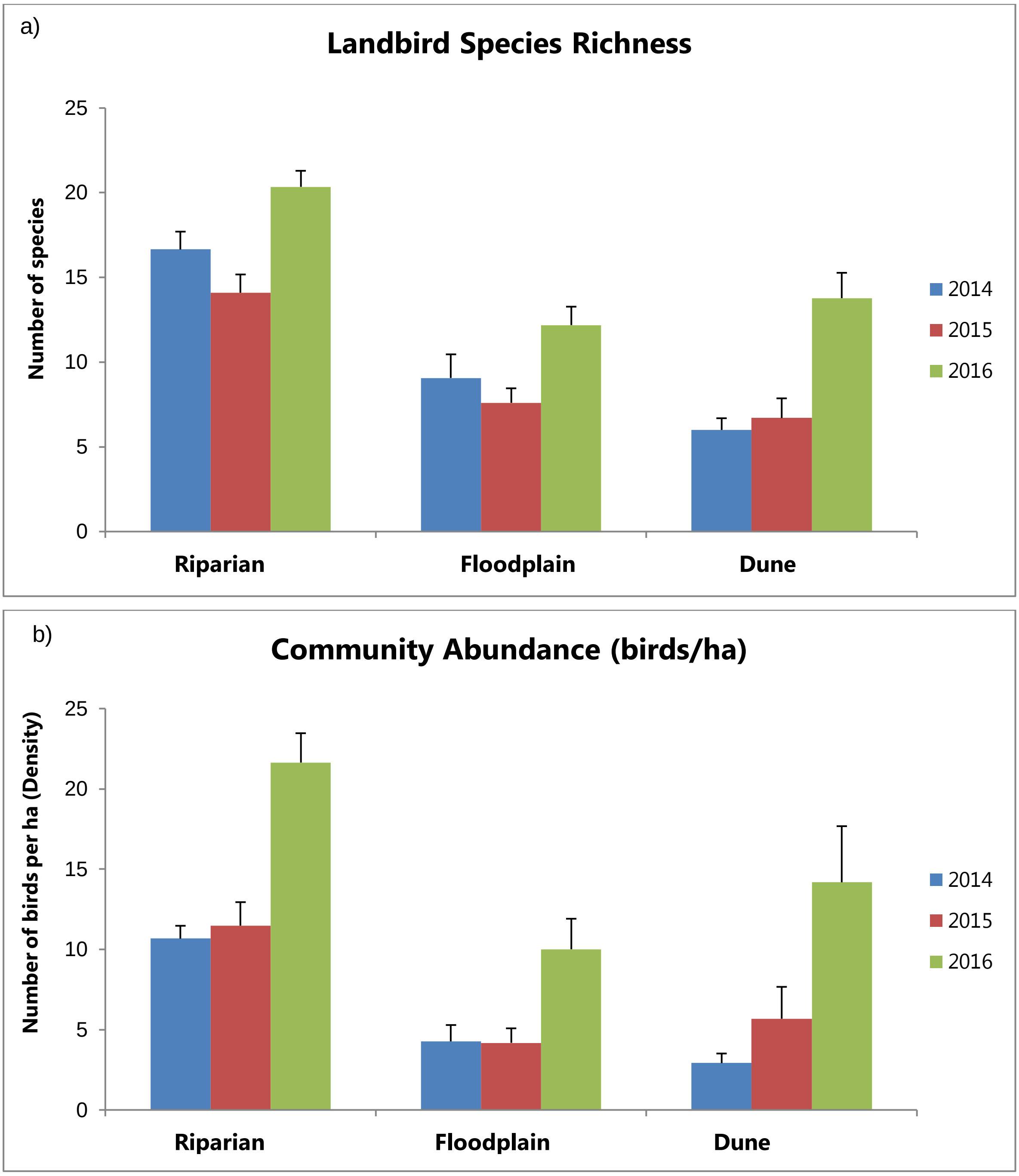
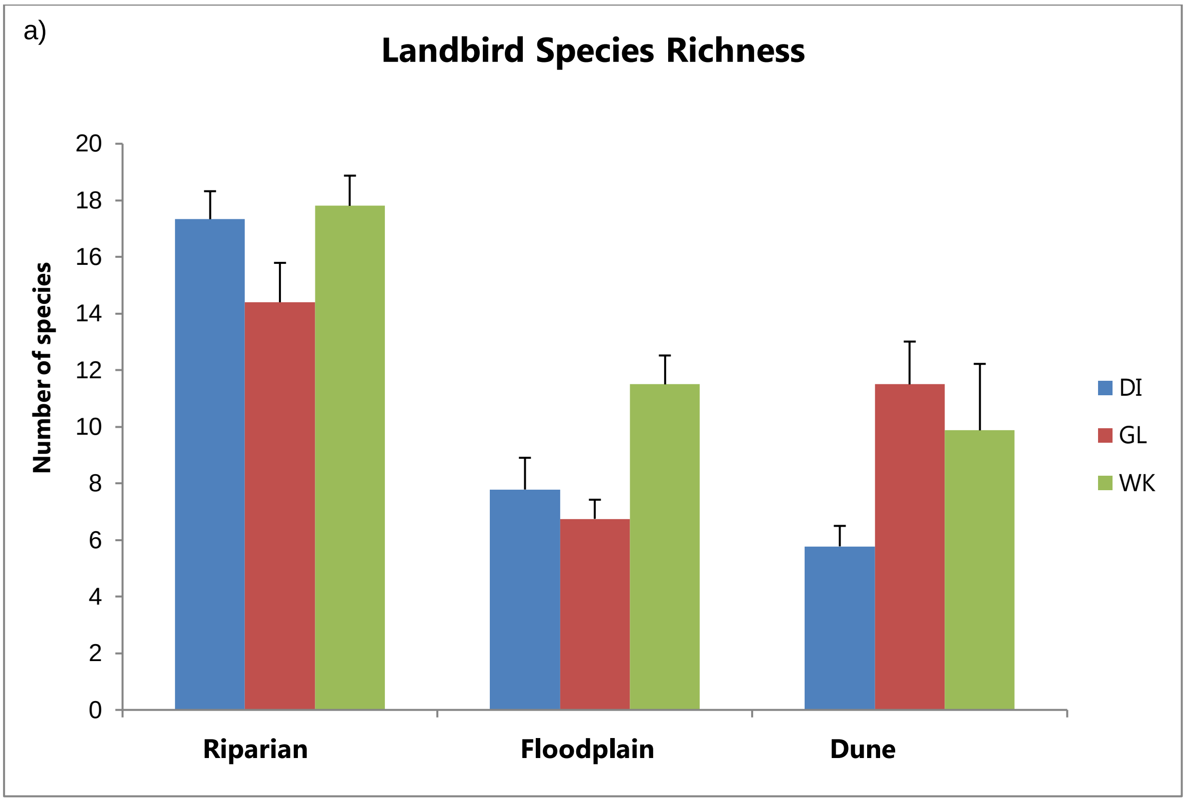


Figure 8 Changes in landbird community species richness (a) and abundance (b) across time for the three main habitats. Mean values (+ 1 se) are plotted



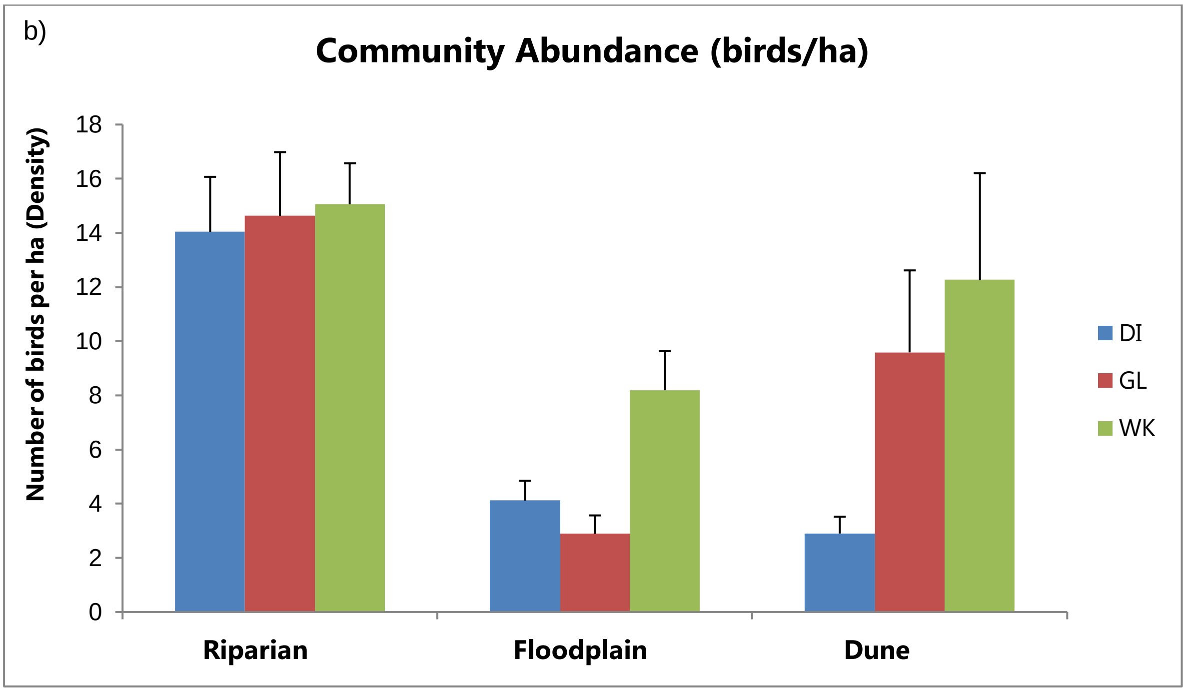


Figure 9 Changes in landbird community species richness (a) and abundance (b) across three main management zones (DI: Diamantina; GL: Goyder Lagoon; WK: Warburton-Kallakoopah) for three habitats. Mean values (+ 1 se) are plotted

Patterns in landbird richness and abundance varied by habitat across properties (Figure 10). Riparian bird communities at both ends of the river system (Pandie Pandie and Kalamurina) had greater richness and abundance than on the other two properties. In all three habitats Kalamurina had more speciose and abundant bird communities than elsewhere, and the relative order in richness and abundance varied across the three other properties by habitat – floodplains on Clifton Hills had the lowest values, while dunes on Pandie Pandie had the lowest values, reflecting the results for management zone (Figure 7).

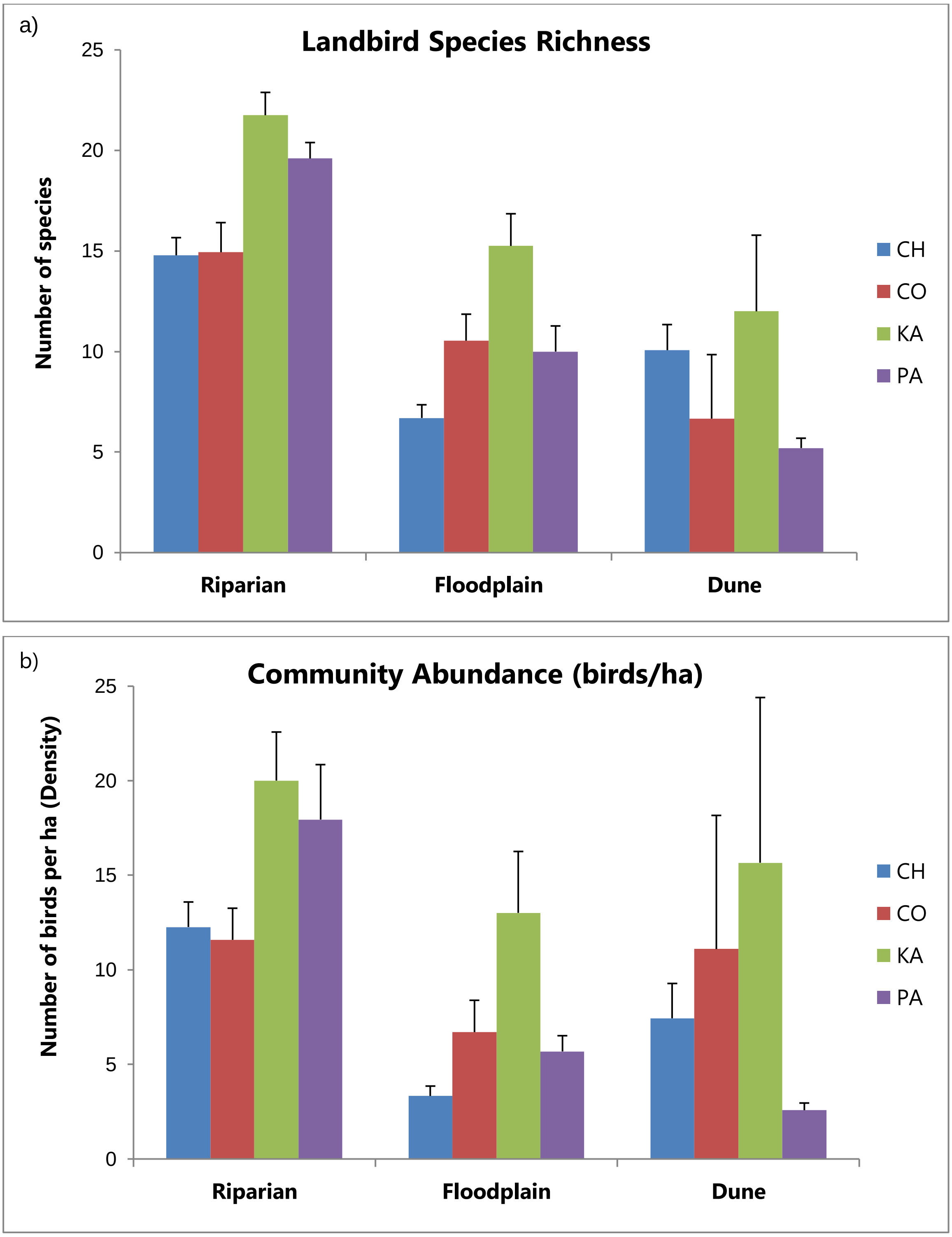


Figure 10 Changes in landbird community species richness (a) and abundance (b) across four properties (CH: Clifton Hills; CO: Cowarie; KA: Kalamurina; PA: Pandie Pandie) for three habitats. Mean values (+ 1 se) are plotted

3.3 Habitat Variation

Principal Components Analysis of 32 plant and habitat variables extracted one dominant axis of environmental variation across the 84 subsites. The first axis alone accounted for nearly 40% of the variance and with the second axis accounted for 53.3% together (Figure 11). Riparian sites, with the exception of Tippipilla Creek, were placed on the right-hand end of axis 1 (PCA1 scores > 1), while most floodplain sites occupied the upper half of the plot (PCA2 scores > 0). Dunes and some floodplain sites on Kalamurina Sanctuary occupied the lower-left quadrant (PCA1 scores < 0, PCA2 scores < 1), and these sites were characterised by two species strongly associated with sandy environments (sandhill canegrass *Zygochloa paradoxa*, and umbrella wattle *Acacia ligulata*), and a greater cover of low ephemeral herbage and bunch grasses, as shown in Figure 11. The riparian sites on Kalamurina also tended to be plotted in negative PCA2 space, again reflecting the greater cover of grasses and ephemeral herbage in the wildlife reserve generally. The cover of Coolibah (Cool) had the greatest loading (0.5) of all attributes on PCA1, followed by Lignum, *Acacia salicina*, hollows, FallLgDT and litter (all > 0.25), while *Z. paradoxa* was negatively loaded on PCA1 (< -0.25). Lignum had the strongest positive loading on PCA2 (Figure 11).

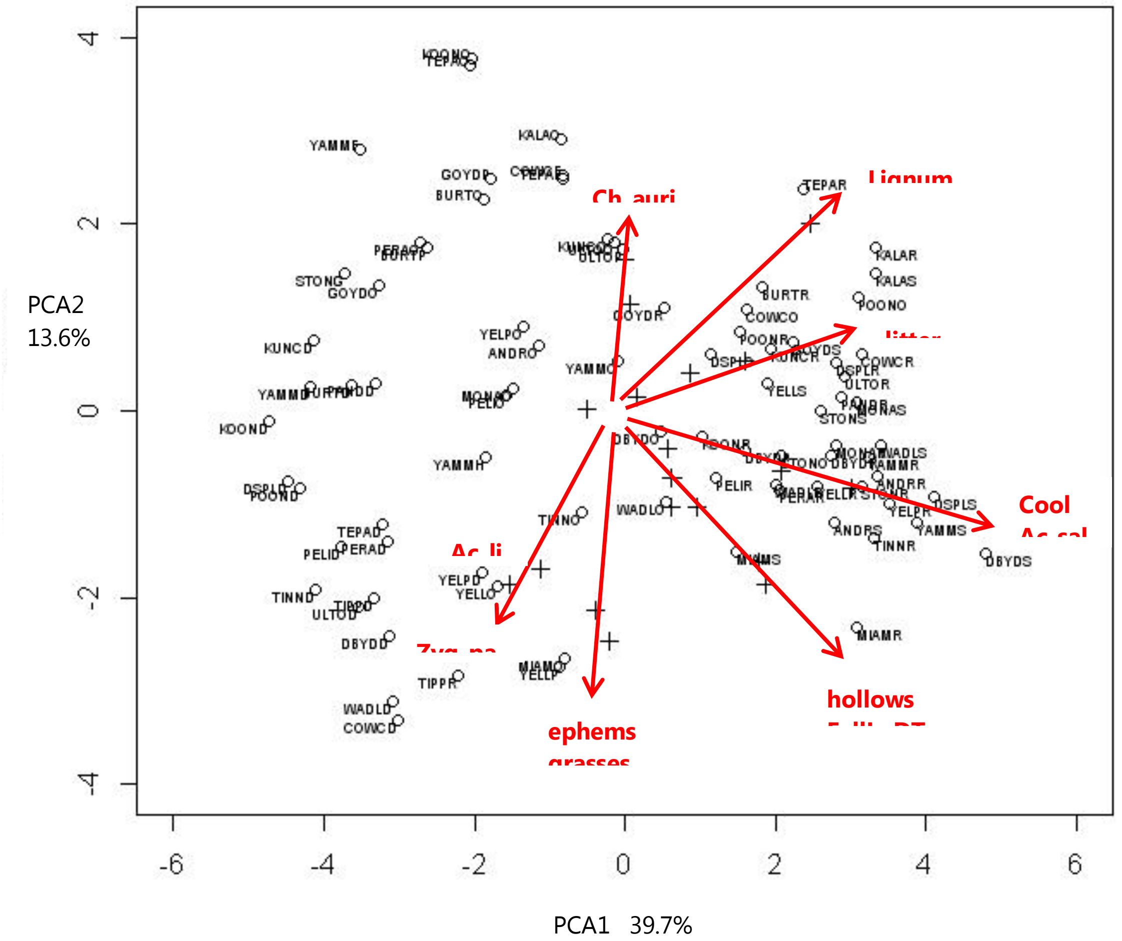


Figure 11 First two axes of PCA of 32 plant and habitat variables, showing 84 subsites. The variables with the strongest loadings (> 0.2) are indicated by red arrows and + symbols

By comparison with the clear patterns in site location on the first two axes of the PCA, there was no obvious clumping by habitat or property identity when subsites were plotted on axes 3 & 4 of the PCA (Figure 12). PCA axis 3 accounted for 9.2% and the fourth PCA axis 5.3% of total variance, and the placement and loadings of the main plant and habitat variables could not be readily interpreted. The habitat variables with loadings >= 0.2 on the first four axes are highlighted in Table 12. Three additional habitat variables had loadings of this magnitude on the fifth or sixth PCA axis, namely Queensland Bean-tree, *Bauhinia gilva* (-0.33 on PCA5, -0.27 on PCA6), 'ruby saltbushes', *Enchylaena tomentosa* and/or *Einadia nutans* (0.36 on PCA6), and fallen small timber, 'FallSmDT' (-0.34 on PCA5, 0.23 on PCA6).

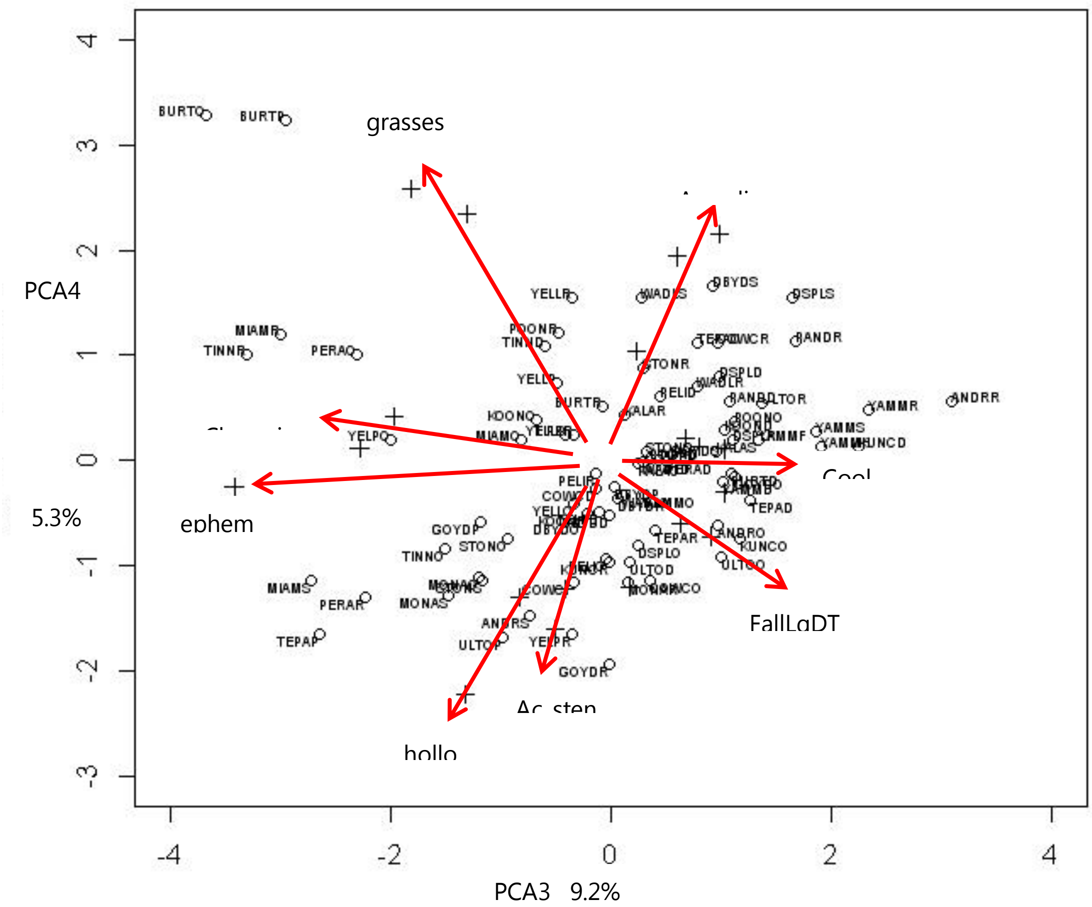


Figure 12 Third and fourth axes of PCA of 32 plant and habitat variables, showing 84 subsites. The variables with the strongest loadings (> 0.2) are indicated by red arrows and + symbols

Table 12 Loadings of most influential plant and habitat variables on the first four axes of the PCA

HabVar	PCA1	PCA2	PCA3	PCA4
Ac_lig	-0.186	-0.282	0.112	0.036
Ac_sali	0.345	-0.106	0.164	0.358
Ac_sten	0.144	0.066	-0.085	-0.267
baregrnd	-0.083	0.002	0.027	-0.200
Ch_auri	-0.001	0.270	-0.381	0.019
Cool	0.500	-0.138	0.172	-0.051
ephems	-0.036	-0.412	-0.571	-0.042
FallLgDT	0.295	-0.271	0.150	-0.120
grasses	-0.064	-0.356	-0.302	0.430
hollows	0.310	-0.310	-0.220	-0.371
Lignum	0.408	0.334	-0.329	0.070
litter	0.265	0.088	0.099	0.323
omsb	0.012	0.189	-0.071	-0.204
sedges	0.026	0.024	-0.219	0.391

HabVar	PCA1	PCA2	PCA3	PCA4
StandDT	0.103	-0.171	-0.139	-0.217
Zyg_para	-0.256	-0.311	0.172	0.018

3.4 Frequency and Abundance of Individual Landbird Species

The most frequently recorded species on transects constitute the most widely distributed species in riparian and floodplain environments in the study area, given the focus on riverine environments, and with over three quarters of transects being situated in these landscapes. From most to less frequent, the most widely distributed species were White-plumed Honeyeater, Willie Wagtail, Crested Pigeon, White-backed Swallow, Zebra Finch, Galah, Tree Martin, Variegated Fairy-wren, Diamond Dove and Black-faced Woodswallow (Table 13). Their frequency ranged from 121 sites occupied by the White-plumed Honeyeater to 58 for the Black-faced Woodswallow.

Zebra Finch, White-plumed Honeyeater, Budgerigar, Masked Woodswallow, Tree Martin, Fairy Martin, White-winged Fairy-wren, Variegated Fairy-wren, Diamond Dove and Eyrean Grasswren had the highest mean abundances on sites at which they were recorded across the study (Table 13), with their mean densities ranging from 0.8-2.4 (ha^{-1}). The list is dominated by flocking species (e.g. Budgerigar, Zebra Finch, woodswallows and martins) and the three group-living Malurid wrens listed. Most of the 10 species are mobile, but the White-plumed Honeyeater and three species of wren are sedentary or loosely so. The mobile species include wide-ranging nomads such as the Budgerigar, semi-migratory/partially nomadic species (Masked Woodswallow, martins) and species which probably range over smaller spatial scales, e.g. Zebra Finch. Five of the most abundant species were also the most widely distributed, and they span a diverse range of niches and ecologies. First, the White-plumed Honeyeater is a generalist honeyeater widely distributed in Australia, and strongly associated with the presence of Coolibah in the region, and the species feeds on insects, nectar when available and sugary plant exudates (e.g. lerps on Coolibahs). Zebra Finch and Diamond Dove are ground-feeding granivores, the former a grass seed feeder. The Tree Martin is a wide-ranging aerial insectivore, strongly associated with riparian environments in the region. Finally the Variegated Fairy-wren is a shrub-dwelling, resident insectivore which tends to avoid more open environments and, amongst the five species, is the only one to maintain a small territory year round. In more open environments, its relative the White-winged Fairy-wren becomes dominant, but both species do occur in all the major environments (provides sufficient shrub cover).

Indicator Species Analysis (IVA) of non-random distributions of bird species across different classes of the four main survey design variables, revealed that all classifications had merit in terms of capturing notable differences in patterns of landbird distribution across the study area (Table 13). More species (24) were significantly non-randomly distributed across the four properties than any other category. Longitudinal trends in bird distribution along the entire river system under study were apparent from the large number of species that were most common on Pandie Pandie (seven species significant) and Kalamurina (15 species) at either end of the system, and with very few species found to be more common on the two properties in between (two species on Clifton Hills, namely Nankeen Kestrel and Fairy Martin: Table 13). Species most likely to be found at higher abundance on Pandie Pandie sites included Red-rumped Parrot, Grey Shrike-thrush, Rufous Whistler, Red-capped Robin and Mistletoebird (and Red-tailed Black Cockatoo was confined to this area). On Kalamurina, the characteristic species included Black Kite, Blue Bonnet, Red-browed Pardalote, Chirruping Wedgebill, Chestnut-crowned Babbler, Black-faced Woodswallow and White-backed Swallow. The inclusion of Black Kite is surprising since this species was absent from the Warburton River in 2014.

Twenty-three species in Table 13 were significantly non-randomly distributed across the three habitat classes, but not one species showed a preference for floodplain habitats. Instead, 19 species were most common at riparian sites, and four – Pallid Cuckoo, Eyrean Grasswren, White-winged Fairy-wren and Singing Honeyeater – on dunes. The most characteristic species of riparian environments (P = 0.001) were Peaceful Dove, Crested Pigeon, Galah, White-plumed Honeyeater, Spiny-cheeked Honeyeater, Yellow-throated Miner, Grey Shrike-thrush, Willie Wagtail, Tree Martin, Australian Raven, Mistletoebird, Magpie-lark and White-breasted Woodswallow.

Table 13 Frequency and mean abundance (mean density: number of individuals per ha) of landbird species across 140 subsites, with results of Indicator Species Analysis (IV) for the four main survey design variables. The ten most frequent species (bold) are listed first, followed by five of the most abundant species (italics), with the remainder in order of decreasing frequency. MaxCls (class in which maximum abundance and frequency were recorded) and probability values (Pval) from IV indicate those species distributed non-randomly across the four factors

			Prop4-IV		Hab3-IV		YrF3-IV		MGZ3-IV	
English Name	**Freq**	**AvAbun**	**MaxCls**	**Pval**	**MaxCls**	**Pval**	**MaxCls**	**Pval**	**MaxCls**	**Pval**
White-plumed Honeyeater	121	2.33	Kalam	0.054	Ripar	**0.001**	2016	0.206	WK	**0.029**
Willie Wagtail	104	0.58	Pand	0.395	Ripar	**0.001**	2016	0.145	GL	0.207
Crested Pigeon	89	0.53	Pand	0.096	Ripar	**0.001**	2014	**0.017**	DI	0.178
White-backed Swallow	83	0.43	Kalam	**0.003**	Ripar	0.083	2014	0.124	WK	**0.023**
Zebra Finch	81	2.42	Kalam	**0.001**	Dune	0.07	2016	**0.001**	WK	0.423
Galah	65	0.77	Cowar	0.092	Ripar	**0.001**	2016	0.233	WK	**0.01**
Tree Martin	64	1.23	CliftH	0.913	Ripar	**0.001**	2016	0.123	GL	0.222
Variegated Fairy-wren	61	0.93	Cowar	0.252	Ripar	0.108	2016	0.975	WK	0.137
Diamond Dove	59	0.89	Kalam	**0.038**	Ripar	0.083	2016	**0.001**	WK	0.067
Black-faced Woodswallow	58	0.53	Kalam	**0.002**	Dune	0.593	2014	**0.029**	WK	**0.019**
Budgerigar	40	2.14	Kalam	**0.018**	Ripar	0.312	2016	**0.001**	WK	0.21
Masked Woodswallow	15	1.95	Cowar	0.456	Ripar	0.74	2016	**0.005**	WK	0.121
Fairy Martin	41	1.17	CliftH	**0.01**	Ripar	**0.024**	2016	**0.005**	GL	**0.001**
White-winged Fairy-wren	43	0.97	CliftH	0.909	Dune	**0.001**	2015	0.845	GL	0.232
Eyrean Grasswren	5	0.80	CliftH	0.862	Dune	**0.001**	2016	**0.043**	WK	0.192
Australian Raven	51	0.27	Kalam	0.949	Ripar	**0.001**	2014	0.607	GL	0.547
Mistletoebird	47	0.48	Pand	**0.015**	Ripar	**0.001**	2016	0.83	DI	0.117
Magpie-lark	45	0.34	Pand	0.972	Ripar	**0.001**	2016	0.962	GL	0.62
Blue Bonnet	40	0.44	Kalam	**0.001**	Ripar	0.134	2016	0.218	WK	**0.001**
Spiny-cheeked Honeyeater	38	0.55	Pand	0.043	Ripar	**0.001**	2014	**0.034**	DI	0.342
White-breasted Woodswallow	37	0.46	Kalam	**0.024**	Ripar	**0.001**	2014	**0.021**	WK	0.754
Peaceful Dove	37	0.36	Pand	**0.034**	Ripar	**0.001**	2014	0.396	DI	**0.002**

			Prop4-IV		Hab3-IV		YrF3-IV		MGZ3-IV	
English Name	**Freq**	**AvAbun**	**MaxCls**	**Pval**	**MaxCls**	**Pval**	**MaxCls**	**Pval**	**MaxCls**	**Pval**
Yellow-throated Miner	35	0.35	Kalam	0.088	Ripar	**0.001**	2016	0.471	WK	**0.03**
Chirruping Wedgebill	35	0.33	Kalam	**0.001**	Ripar	**0.005**	2016	0.156	WK	**0.001**
Little Corella	32	0.74	Kalam	**0.002**	Ripar	**0.004**	2016	**0.036**	WK	0.484
Red-browed Pardalote	32	0.17	Kalam	**0.001**	Dune	0.809	2016	**0.002**	WK	**0.018**
Black-faced Cuckoo-shrike	31	0.31	Kalam	**0.004**	Ripar	**0.02**	2016	0.065	WK	0.456
Whistling Kite	30	0.28	Pand	0.188	Ripar	**0.001**	2016	0.118	DI	0.09
Horsfield's Bronze-Cuckoo	30	0.23	Kalam	**0.009**	Dune	0.296	2016	**0.029**	WK	0.524
Black Kite	29	0.50	Kalam	**0.001**	Ripar	0.186	2016	**0.001**	WK	0.2
Red-backed Kingfisher	29	0.20	Kalam	0.057	Ripar	0.063	2016	**0.001**	GL	0.558
Grey Shrike-thrush	27	0.55	Pand	**0.001**	Ripar	**0.001**	2016	0.961	DI	**0.001**
Chestnut-crowned Babbler	25	0.42	Kalam	**0.006**	Ripar	0.063	2014	0.236	WK	**0.001**
Rufous Whistler	21	0.21	Pand	**0.027**	Fldpl	0.947	2016	**0.041**	DI	0.317
Red-capped Robin	14	0.48	Pand	**0.004**	Dune	0.147	2015	0.133	DI	**0.021**
Red-rumped Parrot	13	0.38	Pand	**0.002**	Ripar	**0.013**	2015	0.718	DI	**0.001**
Striated Pardalote	11	0.25	Kalam	0.095	Fldpl	0.376	2014	0.128	WK	**0.05**
Nankeen Kestrel	11	0.24	CliftH	**0.007**	Dune	0.17	2015	0.101	GL	**0.005**
Common Bronzewing	11	0.22	Cowar	0.111	Ripar	0.171	2014	0.055	WK	0.062
Crimson Chat	10	0.38	Cowar	0.865	Dune	0.438	2016	0.377	WK	0.317
Rufous Songlark	8	0.29	Kalam	**0.005**	Ripar	0.105	2016	0.095	WK	**0.019**
Singing Honeyeater	8	0.24	CliftH	0.252	Dune	**0.004**	2016	0.832	GL	**0.001**
Australian Magpie	7	0.21	Cowar	0.093	Ripar	0.445	2015	0.96	DI	0.883
White-browed Woodswallow	6	0.57	Cowar	0.087	Ripar	0.661	2016	0.615	WK	0.156
White-browed Babbler	5	0.62	CliftH	0.297	Ripar	0.13	2014	0.677	DI	**0.003**
Cockatiel	5	0.16	Kalam	0.661	Ripar	0.247	2016	**0.047**	WK	0.741
Pallid Cuckoo	4	0.18	CliftH	0.108	Dune	**0.005**	2016	**0.015**	GL	**0.027**
Grey Grasswren	3	0.73	CliftH	0.283	Fldpl	0.095	2015	0.669	GL	**0.017**

Twenty-one species in Table 13 were significantly non-randomly distributed across the three main management zones, and species typical of the Diamantina zone were much the same as those identified for Pandie Pandie above and similarly with the Warburton-Kallakoopah zone and Kalamurina. The five characteristic species of Goyder Lagoon sites were Nankeen Kestrel, Pallid Cuckoo, Grey Grasswren, Singing Honeyeater and Fairy Martin, species that occur frequently in open environments with few trees. Fewer species (18) were non-randomly distributed by year of survey, probably because the counterveiling, largely orthogonal effect of habitat made trend detection difficult. No species was characteristic of the second survey in 2015, despite this survey producing the most remarkable observations of rare and other notable bird species (Spotted Bowerbird, Painted Honeyeater, Golden Whistler, Olive-backed Oriole, Tawny Grassbird etc). Four species were found significantly more commonly in 2014, namely Crested Pigeon, Spiny-cheeked Honeyeater, Black-faced Woodswallow and White-breasted Woodswallow ($0.01 < \text{all } P < 0.05$), and Common Bronzewing was recorded most frequently in 2014 ($P = 0.055$), but few of these results were convincing upon inspection of the raw data, since the pigeon and woodswallow species remained widespread and common in subsequent years. However, many species were strikingly more frequent and abundant in 2016 than in other years, and included Black Kite, Diamond Dove, Budgerigar, Red-backed Kingfisher, Red-browed Pardalote, Masked Woodswallow, Fairy Martin and Zebra Finch (all $P <= 0.005$). Of these only the Red-browed Pardalote is not known to be a highly mobile species (Higgins & Peter 2002), and it is likely that the species was overlooked to a degree in previous years, perhaps due to reduced calling activity. Movement into the region by many species in 2016 and some rapid local breeding activity (Zebra Finch) contributed to these results.

3.5 REML Models

Detailed results are presented only for the untransformed variable, 'Rich' (landbird species richness), as results were similar for the transformed variables, 'sqrtS' and 'sqtAb'. Use of the untransformed response variable allows ready interpretation of the results (effects size, residuals etc) in terms of number of species. The year in which surveys were conducted had a highly significant influence on the number of species seen on a transect (change in deviance = 34.87, on 2 d.f., $P < 0.001$) with, on average, between four and five species more seen in 2016 than in the previous two years (Table 14a: random intercept model). Accounting for the repeated-measures correlated errors structure in the random-effects component of the (random slope) model resulted in a marginally significant reduction in deviance (Table 14a), but since the change in deviance was not as great in more complex models with additional fixed terms added, the simpler random effects model was retained. A plot of the Pearson residuals vs the fitted values from the random intercept model reveals that the model is inadequate to describe a significant trend in the data shown by the smoother in Figure 13; transects having low species richness were generally overestimated by just under two species (negative residuals) and transects having high species richness were underestimated by two or more species (positive residuals).

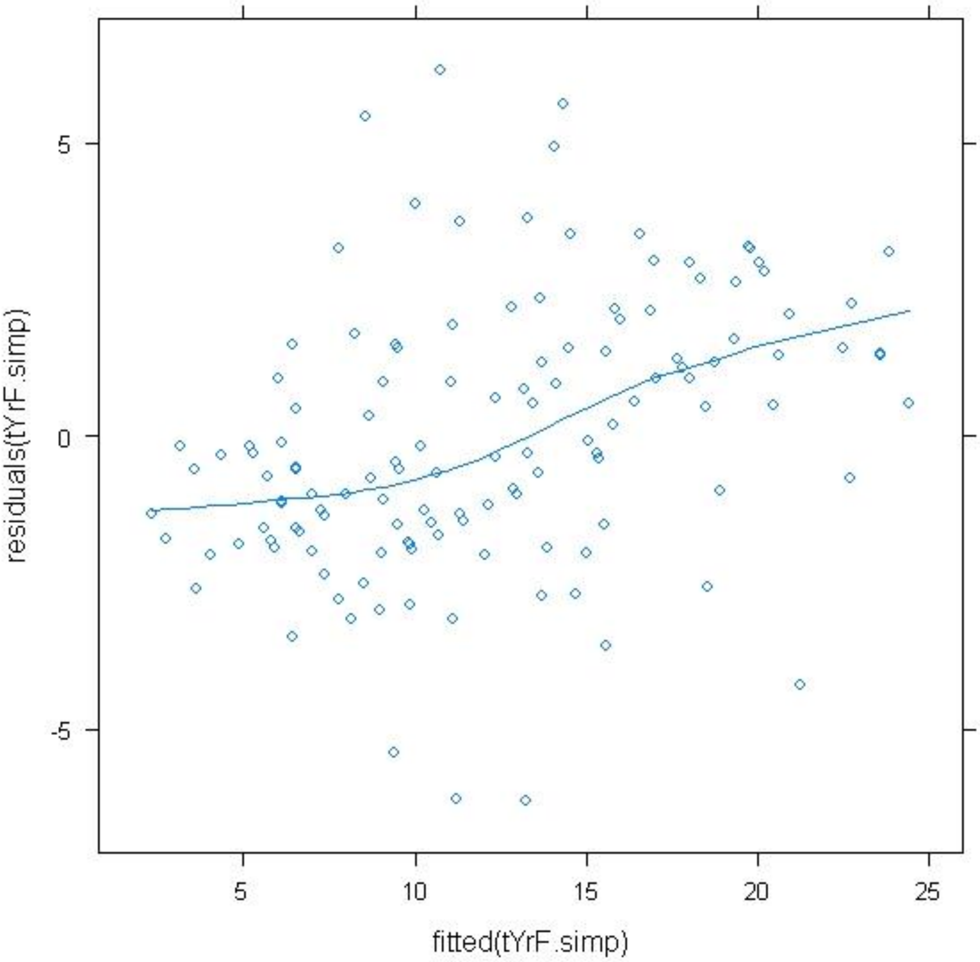


Figure 13 Plot of Pearson residuals vs fitted values of Rich from REML model, 'tYrF.simp', with the factor Year the only fixed effect. The smoother shows a strong positive trend in residuals

Management zone did not significantly influence species richness (Table 14b, nor abundance). The identity of the properties on which sites were located significantly added to the model fit (change in deviance = 13.80, on 3 d.f., $P < 0.01$) with fewest species seen at Clifton Hills' sites, and an additional six species, on average, at Kalamurina sites (Table 14b).

Table 14 REML models of landbird species richness as a function of the survey design variables year, management zone and property identity, and habitat, presented in increasing order of complexity from a) year alone, and with the addition of b) management zone and/or property, and c) habitat.
LRT: likelihood ratio tests comparing simpler and more complex models, using the change in deviance (chng_dev) assessed with Chi-squared distribution on the difference in degrees of freedom (df).
Where all levels of a factor have a *t* value < 2, as with ManagZone in b), the factor is unlikely to be significant, but formal LRTs were undertaken to assess actual significance

a) Comparison of models tYrF.simp and tYrF					
Fixed effects: YrF					
Random effects / model	**Fixed_Eff**	**Estimate**	**Std_Error**	***t*_value**	**Pr(>Chisq)**
1|Site + 1|subsite	Intercept	11.094	0.772	14.365	
tYrF.simp	YrF_Y15	-0.444	0.711	-0.624	
	YrF_Y16	4.234	0.809	5.232	

a) Comparison of models tYrF.simp and tYrF					
Fixed effects: YrF					
YrF|Site + 1|subsite	Intercept	11.285	0.918	12.297	
tYrF	YrFY15	-0.997	1.031	-0.967	
	YrFY16	3.803	0.881	4.317	
LRT		**chng_dev:**	**10.17**	**df = 5**	0.071

b) Adding ManagZone and Prop					
Fixed effects: YrF + ManagZone, or YrF + Prop					
Model	**Fixed_Eff**	**Estimate**	**Std_Error**	**t_value**	**Pr(>Chisq)**
YrF + ManagZone (MZ)	Intercept	10.246	1.304	7.856	
	YrFY15	-0.257	0.715	-0.360	
	YrFY16	4.263	0.809	5.269	
	MZ_EY	-0.290	3.089	-0.094	
	MZ_GL	-0.879	1.743	-0.505	
	MZ_WK	2.191	1.531	1.432	
LRT (compared w tYrF.simp)		**chng_dev:**	**4.84**	**df = 3**	**0.184**
YrF + Prop	Intercept	9.362	1.002	9.345	
	YrFY15	-0.120	0.712	-0.169	
	YrFY16	4.009	0.804	4.985	
	PropCowar	1.184	1.533	0.772	
	PropKalam	6.013	1.609	3.737	
	PropPandie	2.020	1.798	1.124	
LRT (compared w tYrF.simp)		**chng_dev:**	**13.8**	**df = 3**	**0.003**

c) Adding Habitat to YrF + Prop2					
Fixed effects: YrF + Prop2 + HabMaj					
Model	**Fixed_Eff**	**Estimate**	**Std_Error**	**t_value**	**Pr(>Chisq)**
	Intercept	6.999	1.037	6.751	
	YrFY15	-0.218	0.694	-0.314	
	YrFY16	3.905	0.764	5.113	
	Prop2Kal	4.555	1.182	3.854	
	HabMajF	0.445	1.100	0.404	
	HabMajG	-4.473	2.634	-1.698	
	HabMajR	7.683	1.074	7.153	
LRT (compared w YrF + Prop2)		**chng_dev:**	**61.89**	**df = 3**	**<0.0e-12**

However, the residuals plot still revealed the same systematic trend described above, indicating more explanatory terms were probably needed. Also, the change in deviance between the fully specified and simpler random effects models was not significant with the term for property fitted (8.52, on 5 d.f., $P > 0.1$: Table 14b). Comparison of models where property identity was coded as the four-level factor, Prop, versus a two-level factor ('Prop2': distinguishing between 'Kalamurina' and the other three stations as 'Other') indicated that the simpler term was sufficient (change in deviance = 1.57, on 2 d.f., $P > 0.1$).

Adding a habitat factor with four levels, i.e. including gibber as a distinct habitat type, greatly improved the model fit ($P << 0.001$: Table 14c). The few gibber sites had generally >4 species less than dune and floodplain sites, while riparian sites had, on average, 7-8 species more. However, contrary to expectation, this greatly improved model did not completely remove the systematic trend in the residuals, in that transects on which larger numbers of bird species were seen were still underestimated by the model. Adding the interaction term for Year and Habitat neither corrected this issue nor improved model fit significantly. Adding the interaction term for Year and Property did not resolve the issue either. Two modifications of the model were required to eliminate most of the increasing trend in residuals when plotted against fitted values. First, a revision of the habitat factor to discriminate between different types of riparian and floodplain sites was needed. Riparian sites could be divided among main channel and distributary (or minor) channel landform types, while floodplains could also be subdivided into two classes depending on the openness of the vegetation (open habitats with at most sparse woody shrub or tree cover versus sites with moderate or greater woody cover). Second, the cover of Broughton Willow at a site proved to be highly influential on the richness and abundance of landbirds. Replacing the four-level habitat term, 'HabMaj', with the six-level term, 'HabMin', and adding the mean cover class of Broughton Willow to the model significantly improved both the fit (change in deviance = 31.45, on 3 d.f., $P < 0.001$: (Table 15) and the pattern of the residuals (Figure 14). The effect of the six-level habitat factor was most pronounced within riparian environments with 3.5 more species being recorded along major channel environments than distributary or minor channels, but more wooded floodplain sites had, on average, 2.5 species more than barish sites, and sand dunes generally had an intermediate level of species richness compared with the two floodplain classes (Table 15): dune habitat included in intercept). The effect of Broughton Willow's cover at a site, measured on a semi-logarithmic scale, was to increase bird species richness by 1.5 for each unit of cover class (Table 15).

Table 15 Improved REML model (tYrFP2H6BrW) of landbird species richness as a function of year, property identity (Prop2), the habitat factor, HabMin, with six levels, and cover of Broughton Willow. The variance estimates for the random effects (1|Site + 1|Site:subsite) are also presented. The standard deviations of the random effects can be interpreted as the expected average difference between species richness at a pair of subsites (1.1) and sites (1.8), while the mean residual of any observation fitted by this model averages *ca* +/- 3.1 species (see Figure 14)

Random Effects: Groups	**Name**	**Variance**	**Std_Dev**	**REMLdev**
Site:subsite	Intercept	1.296	1.138	738.6
Site	Intercept	3.146	1.774	
Residual	-	9.661	3.108	
Fixed effects: YrF + Prop2 + Ac_sali + HabMin				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
	Intercept	6.628	0.945	7.015
	YrFY15	-0.038	0.697	-0.054
	YrFY16	4.282	0.768	5.577
	Prop2Kal	4.164	1.253	3.323
	Ac_sali	1.547	0.523	2.957
	HabMinFo	-0.803	0.958	-0.838
	HabMinFr	1.711	1.134	1.508

Random Effects: Groups	Name	Variance	Std_Dev	REMLdev
	HabMinGi	-3.821	2.084	-1.834
	HabMinRr	6.117	1.495	4.091
	HabMinRs	2.688	1.288	2.086

The influence of Coolibah was not significant when added to the above model, and even when using the coarser measures of habitat type (the two-level term, 'Hab2', and four-level HabMaj) in REML models Coolibah could only be included as a weakly significant term (both $P < 0.05$) and its effects were small (increases of 0.80 and 0.85 species per unit of cover class, compared with 2.0 extra species for Broughton Willow. Also the REML deviance criterion at convergence (738.6 in the tYrFP2H6BrW model shown in Table 15, with the six-level habitat term, with 13 d.f.) was much lower than the models including Coolibah cover and coarser habitat terms. For example, deviance criterion at convergence for the model 'tYrFP2H4CoolBrW', with the four-level habitat term, was 749.8 (12 d.f.). A formal likelihood ratio test indicated that the former model was superior (change in deviance = 7.61, on 1 d.f., $P < 0.006$).

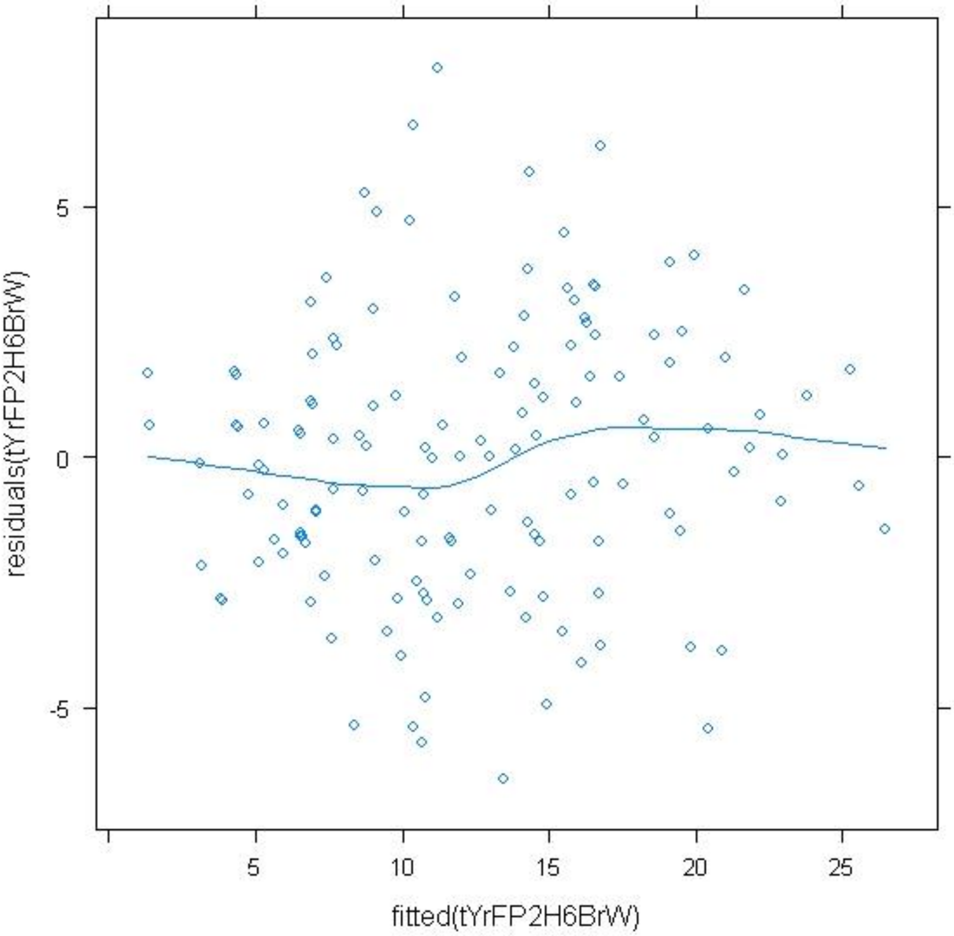


Figure 14 Plot of Pearson residuals vs fitted values of Rich from REML model, 'tYrFP2H6BrW', with Year and subsite as random effects. The smoother shows no consistent linear trend in residuals

REML Models with PCA Habitat Terms

Fitting the PCA habitat variables to landbird species richness revealed that five of the six retained PCA scores could be fitted as significant terms, in combination, to a REML model of Rich containing Year and a new independent variable, 'NSTsp', and with the same random terms (Site, Site:subsite; Table 16a). Preliminary modelling had indicated that the number of small tree species (NSTsp) at a site was a powerful positive correlate of landbird richness. The four species of small tree in the region included in this variable were Broughton Willow, River Cooba *Acacia stenophylla*, Whitewood *Atalaya hemiglauca*, and Native Apricot *Pittosporum angustifolium*. The last species was restricted to one riparian site, and so it was largely the joint presence of the other three species at sites that appeared to be an important habitat attribute. Although we have already demonstrated the influence of Broughton Willow on bird species richness, the other two small tree species were not selected as significant independent variables in subsequent stepwise modelling procedures.

Two PCA models are presented in Table 16, and in the second, more complex model with year, HabMin, Prop2 and NSTsp also fitted, four PCA variables could be fitted in combination (Table 16b). The negative sign of the coefficient for PCA2 in the first model is a consequence of the sign of the loadings (Table 13) of most of the influential habitat variables also being negative. The fact that so many PCA composite variables could be included as significant terms in models suggested that there was scope for building more complex models using the actual plant and other habitat variables.

Table 16 REML models including PCA composite variables

a) Fixed effects: YrF + NSTsp + 5 PCA variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 748.5	Intercept	9.371	1.003	9.346
df = 12	YrFY15	-0.253	0.658	-0.385
	YrFY16	4.290	0.753	5.700
	PCA1	1.132	0.192	5.888
	PCA4	1.818	0.361	5.041
	PCA2	-0.779	0.235	-3.310
	PCA6	1.872	0.431	4.340
	PCA5	1.391	0.407	3.414
	NSTsp	1.067	0.497	2.147

b) Fixed effects: YrF + HabMin + Prop2 + NSTsp + 4 PCA variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 716.3	Intercept	8.096	1.528	5.299
df = 17	YrFY15	0.141	0.683	0.206
	YrFY16	5.063	0.753	6.725
	HabMinFo	-1.529	1.118	-1.368
	HabMinFr	-2.455	1.639	-1.505
	HabMinGi	-1.350	1.954	-0.691
	HabMinRr	2.109	2.119	0.995
	HabMinRs	-2.307	2.007	-1.150
	Prop2Kal	2.544	1.143	2.226
	PCA1	0.764	0.311	2.453
	PCA6	1.714	0.427	4.018

b) Fixed effects: YrF + HabMin + Prop2 + NSTsp + 4 PCA variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
	PCA4	1.068	0.367	2.953
	PCA5	1.431	0.468	3.099
	NSTsp	1.573	0.489	3.214

REML Models with Multiple Habitat Terms

Two multi-variable habitat models are presented for untransformed landbird species richness, both with the same random effects as specified before and with the year, Prop2, HabMin and NSTsp terms included. In the first, in which Broughton Willow was deliberately retained, and in which only plant species or groups were included, four other variables were added in forward stepwise selection (Table 17). The results show that for each additional cover class unit of Lignum and Old Man Saltbush (omsb) approximately one extra landbird species could be expected, while additional cover of Broughton Willow, Ruby Saltbushes and Sandhill Canegrass would each add more than one extra species. This model, with the number of small tree species (NSTsp) present also a significant contributor to increased landbird richness, shows that shrubby cover in riparian and floodplain environments and Sandhill Canegrass on dunes and in other sandy environments are important components of habitat quality in the study region. It should be noted that these complex, multi-variable models with d.f. > 14 (also Table 16b) run the risk of over-fitting, but they are presented in order to provide support for the notion that multiple habitat strata (low shrubs, larger shrubs, small trees etc) and the presence and health of dominant woody plant species, e.g. Coolibah (the effects of which are subsumed in the habitat term and other covariates fitted), are important to landbirds in the region. There is no evidence these complex models suffer from multicollinearity, as the coefficients (for survey design variables such as year and habitat) and variance component estimates are fairly stable and consistent with the estimates in simpler REML models presented earlier. However, there was also no further improvement in the distribution of residuals.

Table 17 One multi-variable REML model of richness including five plant variables

Fixed effects: YrF + HabMin + Prop2 + NSTsp + 5 habitat variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 717.0	Intercept	0.285	2.071	0.138
df = 18	YrFY15	-0.264	0.686	-0.384
	YrFY16	4.200	0.743	5.650
	HabMinFo	2.092	1.818	1.151
	HabMinFr	3.261	1.942	1.679
	HabMinGi	1.791	2.635	0.680
	HabMinRr	6.072	2.162	2.808
	HabMinRs	2.519	2.045	1.232
	Prop2Kal	3.066	1.198	2.560
	NSTsp	1.005	0.429	2.343
	Ac_sali	1.479	0.526	2.810
	Ench_Ein	1.688	0.683	2.471
	Zyg_para	2.516	0.806	3.121
	Lignum	0.934	0.440	2.122
	omsb	0.991	0.501	1.979

Table 18 A multi-variable REML model of bird species richness including five habitat variables which had the lowest deviance at convergence with all included terms significant

Fixed effects: YrF + HabMin + Prop2 + NSTsp + 5 habitat variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 701.2	Intercept	-2.250	2.095	-1.074
df = 18	YrFY15	0.113	0.663	0.171
	YrFY16	4.504	0.696	6.469
	HabMinFo	2.360	1.693	1.394
	HabMinFr	3.129	1.780	1.758
	HabMinGi	1.597	2.383	0.670
	HabMinRr	7.793	1.774	4.394
	HabMinRs	2.960	1.765	1.677
	Prop2Kal	3.136	1.000	3.136
	NSTsp	0.933	0.385	2.421
	litter	1.697	0.415	4.085
	Ench_Ein	1.796	0.580	3.099
	Zyg_para	2.712	0.717	3.785
	Sen_cunn	2.666	0.748	3.564
	Ac_murr	-2.272	0.919	-2.472

The REML model having the lowest reduction in deviance in which all (fixed effect) terms could be dropped and added during the stepwise selection process resulted in the inclusion of some surprising habitat variables (Table 20). The same terms for year, habitat (six levels) and property (two levels) were selected, with similar coefficients and levels of significance as in simpler models presented above. The significant influence of small trees (NSTsp) was again supported, with an additional landbird species expected for each addition of a small tree species. Of the additional habitat variables selected, the abundance of litter had the most significant effect on landbird richness with each extra unit of litter cover predicted to result in an extra 1.7 bird species. The Ruby Saltbushes had a similar effect to litter (Table 20). Cover of Sandhill Canegrass was again highly influential (2.7 extra species per unit cover), while two new plant species were selected in this model. First, increasing cover of the perennial daisy, *Senecio lanibracteus* (Sen_cunn), was a highly significant predictor (2.7 extra species per unit cover), while the presence and increasing cover of the Colony Wattle, *Acacia murrayana* (Ac_murr), had negative effects on landbird species richness (Table 20), with the predicted reduction of 2.3 bird species for each extra unit of cover.

REML Models of Bird Species Richness with Coolibah Included

The distribution and cover of Coolibahs across sites were highly associated with the habitat classifications. Fitting simple linear models without random effects, Hab2 explained 56% (adjusted R^2) of the variation in Coolibah cover class scores, while HabMin explained 77%. Therefore, to build REML models od bird species richness with Coolibah as an independent variable, habitat terms were deliberately excluded. Two REML models are presented. Stepwise modelling containing year, Prop2 and Cool allowed five significant plant terms to be added (Table 19), and the species, their effect size and sign of the coefficients were similar to those of several previous models. A unit increase in cover of Broughton Willow, Ruby Saltbushes and Sandhill Canegrass was predicted to add an extra two landbird species at a site, while for Colony Wattle there would two less species. The influence of Lignum was again highly significant and positive on bird species richness, although its effect was slightly smaller (1.25 species added for unit cover increase).

Table 19 A multi-variable REML model of bird species richness which included Coolibah and five other significant plant variables

Fixed effects: YrF + Prop2 + Cool + 5 plant variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 742.1	Intercept	2.773	1.033	2.684
df = 13	YrFY15	-0.321	0.683	-0.471
	YrFY16	3.989	0.735	5.430
	Prop2Kal	2.283	1.167	1.957
	Cool	0.811	0.364	2.229
	Ac_sali	1.906	0.461	4.133
	Zyg_para	2.021	0.513	3.939
	Ench_Ein	2.048	0.678	3.019
	Lignum	1.252	0.392	3.197
	Ac_murr	-2.143	1.042	-2.056

Table 20 A multi-variable REML model of square root of landbird species richness which included Coolibah and five other significant plant variables

Fixed effects: YrF + NSTsp + Cool + 5 plant variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 246.5	Intercept	1.720	0.167	10.319
df = 13	YrFY15	-0.069	0.102	-0.677
	YrFY16	0.640	0.113	5.683
	Cool	0.123	0.061	2.008
	Ac_sali	0.264	0.071	3.718
	Ac_lig	0.379	0.086	4.436
	Lignum	0.168	0.060	2.792
	Ench_Ein	0.302	0.096	3.138
	NSTsp	0.170	0.064	2.674
	omsb	0.158	0.080	1.970

For the second model the square root of bird species richness was used as the response (same random effects: Site and Site:subsite). The property identity term was dropped through the stepwise process, and the term for the number of small trees, NSTsp, was included, along with Coolibah. Again five additional plant species terms could be added to the model, with three terms (Ac_sali, Lignum and Ench_Ein) the same as in Table 19 and at similar levels of significance (judging by the *t* values: Table 20). Umbrella Wattle *Acacia ligulata* appeared to be substituted for Sandhill Canegrass, given both plants occupy dune and sandy environments, while Old Man Saltbush, with a positive effect, was added at the expense of Colony Wattle. Both models emphasise the importance of dominant plant species, particularly shrubs, in the region's major environments in making a significant contribution to the maintenance of bird diversity in dryland habitats. With multiple habitat terms included, we again note the inclusion of Coolibah in these models was only weakly supported ($t \approx 2.0$, $P < 0.05$).

REML Model of Transformed Response Variables

Many models of log-transformed and square-root transformed species richness and total abundance were considered, and generally the results were very similar to those presented for untransformed richness (models not presented). Given the very tight relationship between community abundance and species richness (on square-root transformed variables, R^2 = 86%), the similarity in modelled responses is unsurprising. However, two models of root-transformed abundance are presented, the second one deliberately including the square root of bird species richness, 'sqrtS', as a covariate. Because inclusion of species richness made the property identity and habitat factors redundant, the first model was built in a stepwise manner without these terms to allow for comparison. It also added some terms not seen in previous results.

Table 21 Stepwise built multi-variable REML models of square root of landbird community abundance as functions of year and individual habitat variables, excluding Prop2 and habitat (a). Random effect terms were Site and subsite. The square root of species richness was included in b)

a) Fixed effects: YrF + NSTsp + 5 habitat variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 330.3	Intercept	-0.151	0.362	-0.415
df = 12	YrFY15	0.161	0.140	1.148
	YrFY16	1.269	0.158	8.032
	Ac_sali	0.492	0.088	5.590
	NSTsp	0.309	0.082	3.788
	StandDT	0.336	0.097	3.451
	Zyg_para	0.461	0.086	5.353
	litter	0.288	0.114	2.523
	sedges	0.274	0.133	2.067

b) Fixed effects: YrF + sqrtS + 4 habitat variables				
	Fixed_Eff	**Estimate**	**Std_Error**	**t_value**
REMLdev = 280.1	Intercept	-0.952	0.255	-3.731
df = 11	YrFY15	0.239	0.119	2.002
	YrFY16	0.719	0.141	5.105
	sqrtS	0.838	0.088	9.563
	Ac_sali	0.279	0.073	3.839
	Zyg_para	0.158	0.070	2.257
	StandDT	0.205	0.082	2.511
	Pt_atr	1.166	0.671	1.738

The model without the covariate, sqrtS, has some similarities to previous models of species richness, in sharing the independent variables, Ac_sali, NSTsp, Zyg_para and litter, but standing dead timber, 'StandDT', and sedges were also included (Table 21a), both these variables having a positive relationship with total bird abundance. However, the significance and influence of several terms were much greater in this model than in previous models of species richness. Bird abundance in 2016 was greatly elevated (t = 8.0), and the significance of Broughton Willow, NSTsp, and Sandhill Canegrass was much greater than in previous models, suggesting that the presence and cover of small trees (particularly Broughton Willow) and Sandhill Canegrass disproportionately elevated bird abundance compared with their effects on species richness. Three of these habitat variables were retained in the second model with the inclusion of sqrtS (namely, Ac_sali, Zyg_para and StandDT), but their significance was reduced (Table 21b), lending support to the notion that certain habitat features had direct influence on bird abundance over and above their effects n species richness. The fourth habitat variable, Pt_atr (Crimson Foxtail *Ptilotus sessilifolius*), was only marginally significant (LRT: change in deviance = 2.97 d.f. = 1, $P < 0.1$) as indicated by its t value in Table 21b, but is presented here given the contention that the likelihood ratio test is conservative with true P values being approximately half that calculated (Bates *et al.* 2016). The inclusion of this low subshrub found mainly in sandy environments may reflect an avian response to the seasonal influence of antecedent conditions (locally higher rainfall perhaps), for which arid-zone Australian birds are renowned (through immigration of nomadic species and rapid breeding in response to good conditions: e.g. Schodde 1982; Reid *et al.* 1993; Burbidge & Fuller 2007; Jordan *et al.* 2017).

3.6 Landbird Assemblages and Multivariate Analyses

Compared with the clearly patterned and interpretable cluster analysis of whole of site avifaunas (Figure 6), the dendrogram of 138 landbird assemblages had little coherence except in having one major split that divided riparian and some floodplain observations from remaining floodplain and dune observations. There was no compelling evidence for runs of observations from the one year or from a single property of management zone. An unconstrained NMDS ordination confirmed the presence of one major division in the data (Figure 15), with riparian (and 'riparian-like' floodplain) assemblages clustered in the negative half of the first (PCS1) axis, and dune and more open floodplain bird assemblages mainly placed in the positive region of the first axis. Figure 15 also shows the plant and habitat variables that correlated strongly with this solution (bolded variables: R_m > 0.3, P <= 0.001), there being 12 variables whose vectors are contained within an arc of *ca* 40° around the negative end of axis 1 (Figure 15a). These variables included typical members of riparian vegetation communities in the study region and those habitat attributes (litter, coarse woody debris, hollows etc) which are abundant in riparian vegetation (Table 22). Coolibah had the strongest association with the unconstrained ordination (R_m = 0.84) followed in strength of relationship by Broughton Willow (R_m = 0.75), and litter and fallen large timber (R_m >= 0.64). At the other end of this primary axis of differentiation the habitat of bird assemblages in dune environments was characterised by two plant species, Umbrella Wattle and Sandhill Canegrass, and the abiotic variable, the amount of bare ground (R_m = 0.49-0.50: Figure 15; Table 22).

Table 22 Plant and habitat variables strongly correlated with 3d ordination of 138 landbird assemblages. R_m: multiple correlation coefficient; P: probability from 999 randomisations

Variables	PCS1	PCS2	PCS3	R_m	P
		Riparian			
Ac_sali	-1.878	-0.089	0.271	*0.745*	0.001
Cool	-1.870	0.182	-0.280	*0.835*	0.001
FallLgDT	-1.848	-0.381	0.226	*0.642*	0.001
Lignum	-1.841	0.322	-0.345	*0.503*	0.001
Sant_lan	-1.816	0.502	-0.247	*0.380*	0.001
hollows	-1.765	-0.640	0.291	*0.559*	0.001
FallSmDT	-1.759	0.471	0.543	*0.411*	0.001
Ac_sten	-1.681	0.271	-0.843	*0.444*	0.001
Er_bign	-1.653	-0.447	-0.824	*0.351*	0.001
litter	-1.646	0.650	0.691	*0.660*	0.001
Ench_Ein	-1.526	-0.413	1.054	*0.486*	0.001
Am_preis	-1.495	-0.565	1.028	*0.418*	0.001

Variables	**PCS1**	**PCS2**	**PCS3**	R_m	***P***
Riparian					
Dunes and sandy					
grasses	0.652	-0.752	1.618	*0.409*	0.001
Ac_murr	1.014	0.580	1.499	*0.357*	0.001
Cyn_flor	1.025	-1.287	0.951	*0.354*	0.001
Ac_lig	1.319	-0.207	1.352	*0.503*	0.001
Zyg_para	1.386	-0.588	1.159	*0.487*	0.001
Floodplain (& gibber)					
rocks	0.554	-0.496	-1.748	*0.379*	0.001
Mitch_gr	0.862	-0.047	-1.693	*0.364*	0.001
Scler_sp	1.158	-0.581	-1.390	*0.362*	0.001
baregrnd	1.573	-0.499	-0.941	*0.503*	0.001
ephems	0.626	-1.606	0.799	*0.433*	0.001
senna	1.177	1.016	1.092	*0.352*	0.001

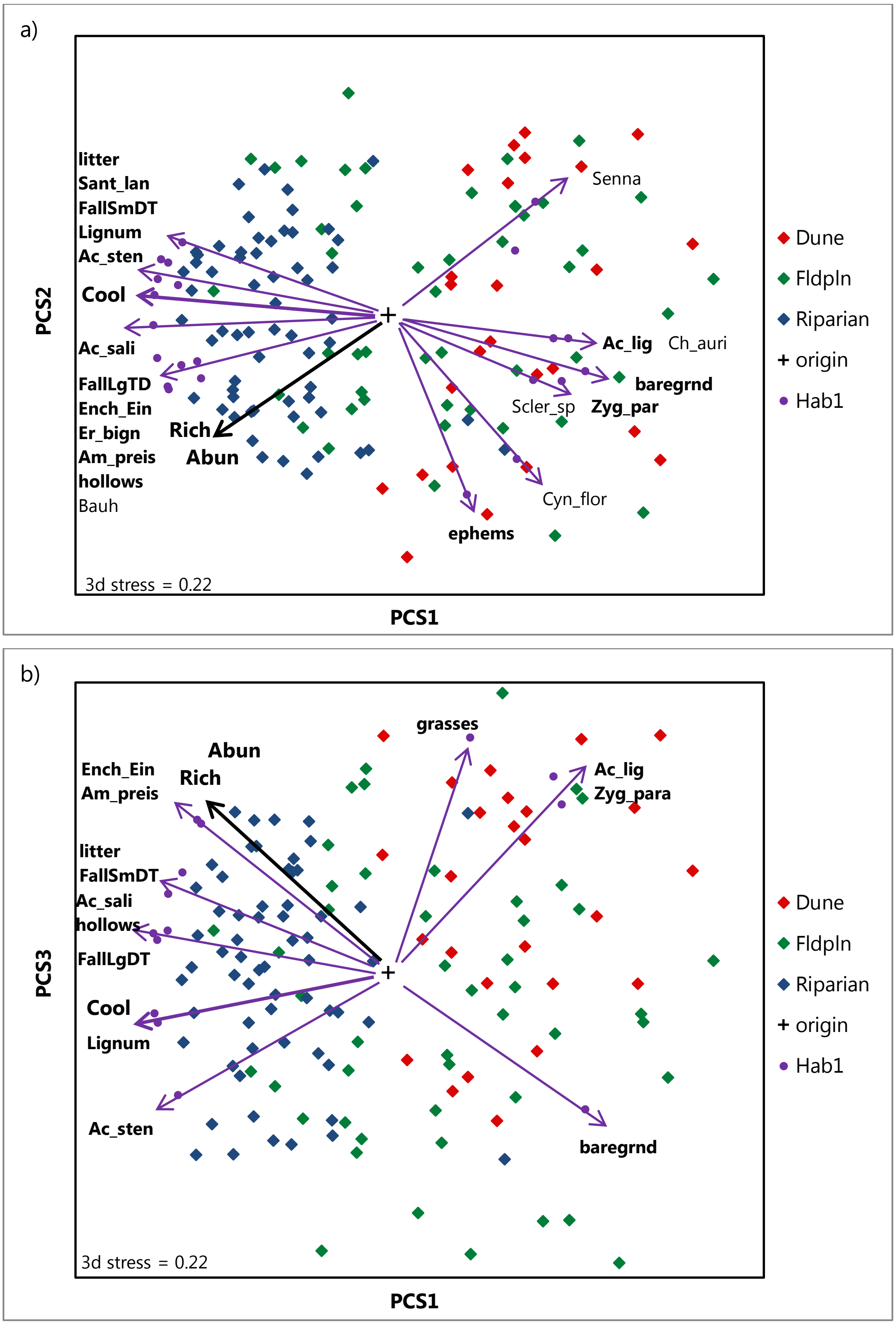


Figure 15 Three dimensional, *q*-mode NMDS ordination of 138 landbird assemblages, with observations plotted by major habitat (two gibber observations excluded); plots of a) axis 2 vs axis 1, and b) axis 3 vs axis 1. Principal axis correlation (PCC) fits of most significant plant and habitat (Hab1) variables shown as vectors. PCC fits (R_m >= 0.8) of avian community abundance (Abun) and species richness (Rich) also shown

It can be seen in Figure 15 that sites with maximum species richness and abundance are placed towards the margins of the whole riparian cluster of observations as indicated by their vectors, and that the reasons why these sites had slightly higher richness and abundance than the average riparian site are not obviously explained by the plant and habitat variables, given the vectors for richness and abundance lie outside the arc of habitat variables. The third axis of the ordination provided the clearest separation between floodplain and dune sites (Figure 16) but, as observed for the dendrogram analysis, these habitat groups did not form discrete clusters in multivariate space. Vectors through the centroids of sites on Clifton Hills and sites in the Goyder Lagoon management zone are also shown in Figure 16, to illustrate their strong affinity with floodplain sites. Centroids for the other three properties and two main management zones plotted closer to the origin, i.e. they did not have as distinctive bird assemblages, instead reflecting the stronger habitat associations.

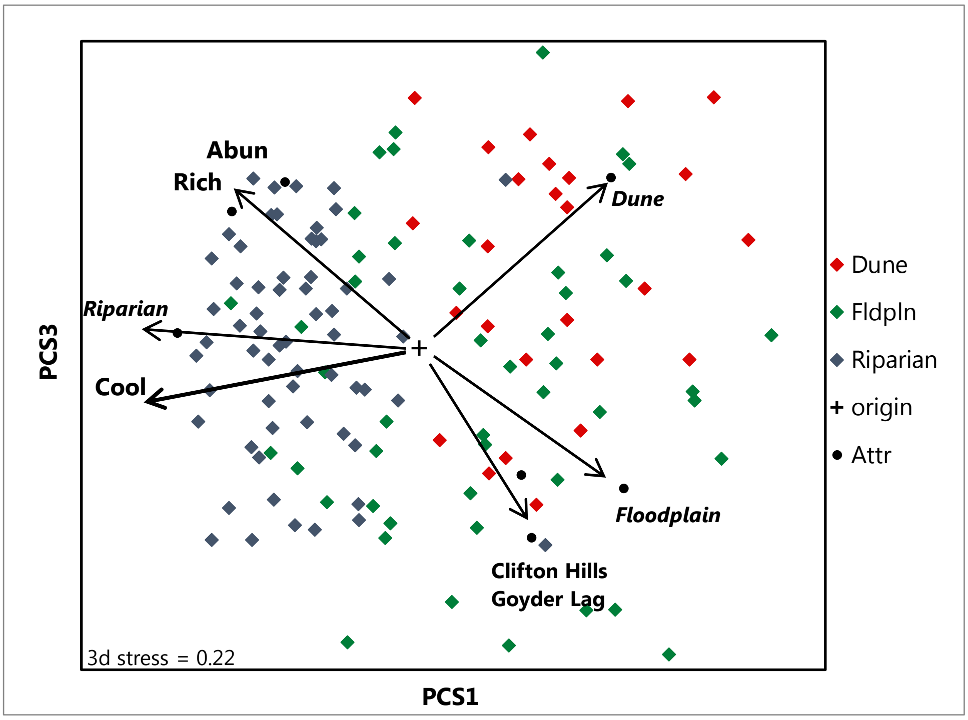


Figure 16 NMDS ordination plot of axis 3 vs axis 1 (as in Figure 15a) with the PCC vectors for the three main habitats (vectors through their centroids), the most strongly correlated plant variable, Coolibah (Cool), and richness and abundance shown as vectors. The PCC vectors for the property, Clifton Hills, and management zone, Goyder Lagoon, centroids are also shown

The second ordination axis strongly reflected the influence of year of survey and a plot of axis 2 vs axis 3, to eliminate the strongest influence of habitat, reveals a clear if incomplete separation of sites according to year (Figure 17). Similar alignments of avian richness and abundance with 2016 observations and also with the cover of grasses and low ephemeral herbage provides at least a partial explanation for why the richness and abundance vectors did not fully line up with riparian sites centrally nor with the main riparian plant and habitat variables in Figure 15. In these two dimensions sites on Kalamurina are most clearly separated from the three cattle stations, and previous REML modelling has indicated bird richness and abundance were higher on Kalamurina.

Some of the bird species responsible for the placement of sites in the ordination are shown in Figure 18. Eight species were strongly associated with the core of riparian sites, namely (from top to bottom at left hand side of plot) Spiny-cheeked Honeyeater, Galah, Crested Pigeon, Mistletoebird, White-plumed Honeyeater, Magpie-lark, Whistling Kite and Willie Wagtail. White-winged Fairy-wren was the only frequently recorded species that exhibited a clear preference for the more open habitats of the dunes and outer floodplain. Several species with vectors pointing down in Figure 18 are birds that became more abundant over time, especially in 2016, namely Little Corella, Budgerigar, Red-backed Kingfisher and Zebra Finch. The plotting together of Eyrean Grasswren (dunes) and Australasian Pipit (barish floodplain) masks their very different habitat preferences evident in their separation on axis 3 (see PCS3 scores in Table 23).

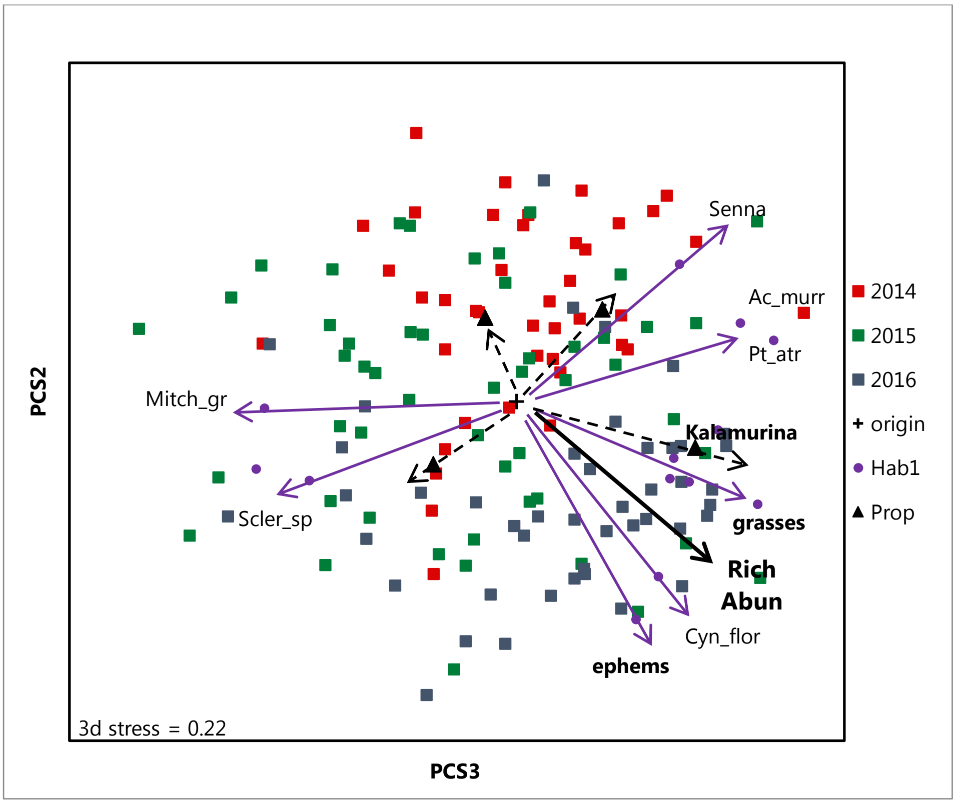


Figure 17 NMDS ordination plot of axis 2 vs axis 3 with sites identified by year of survey. The few PCC vectors of significantly correlated plant and habitat variables (*P* <= 0.005), with affinity to sites in both these dimensions, are shown. Vectors through the centroids of the four properties show the clear separation of Kalamurina from the other three

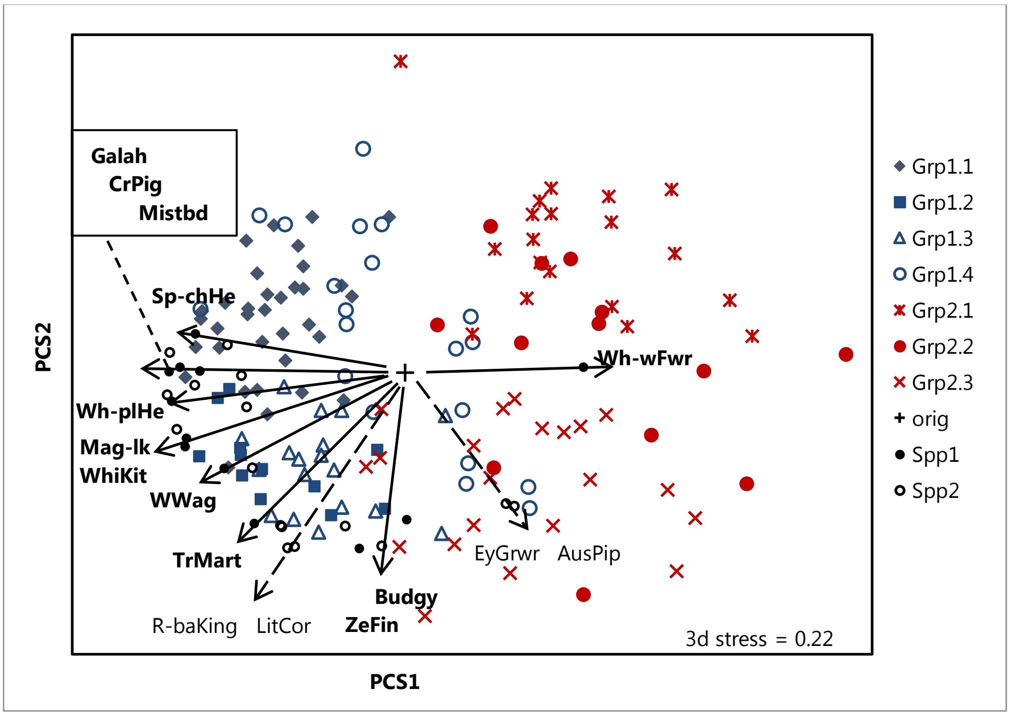


Figure 18 NMDS ordination plot of axis 2 vs axis 1 with sites identified by dendrogram groupings. PCC vectors show significantly correlated bird species (Spp1 in bold: *P* = 0.001; Spp2 plain: *P* <= 0.005). Keys to species' abbreviations presented in Table 23

Table 23 Bird species strongly correlated with and responsible for 3d ordination of 138 landbird assemblages. R_m: multiple correlation coefficient. Probabilities from 999 randomisations were 0.001 except for three species asterisked, where $P < 0.01$. Abbreviations (Abbrv) are given for the species plotted in Figure 18. Species with large negative scores on PCS1 (bold) have strong affinities with riparian sites. Species with large negative scores on PCS2 were more frequent or abundant in 2016

Code	Abbrv	English Name	PCS1	PCS2	PCS3	R_m
B625	Wh-plHe	White-plumed Honeyeater	**-0.976**	-0.140	0.170	*0.870*
B535	Wh-wFwr	White-winged Fairy-wren	**0.741**	0.027	0.671	*0.716*
B653	ZeFin	Zebra Finch	0.005	**-0.724**	0.689	*0.712*
B359	TrMart	Tree Martin	-0.632	**-0.745**	-0.215	*0.614*
B364	WWag	Willie Wagtail	**-0.756**	-0.472	0.454	*0.610*
B310	Budgy	Budgerigar	-0.193	**-0.869**	0.457	*0.564*
B273	Galah	Galah	**-0.987**	0.005	0.160	*0.525*
B043	CrPig	Crested Pigeon	**-0.940**	0.028	0.340	*0.516*
B358		White-backed Swallow	-0.573	0.261	**0.777**	*0.508*
B564	Mistbd	Mistletoebird	**-0.857**	0.008	0.516	*0.489*
B640	Sp-chHe	Spiny-cheeked Honeyeater	**-0.878**	0.191	0.439	*0.486*
B415	Mag-lk	Magpie-lark	**-0.915**	-0.324	0.242	*0.483*
B228	WhiKit	Whistling Kite	**-0.920**	-0.366	0.138	*0.482*
B360		Fairy Martin	-0.462	**-0.857**	-0.228	*0.458*
B930		Australian Raven	**-0.994**	-0.109	-0.017	*0.449*
B030		Peaceful Dove	**-0.955**	-0.280	0.095	*0.446*
B408		Grey Shrike-thrush	**-0.982**	0.100	0.159	*0.416*
B325	R-baKing	Red-backed Kingfisher	-0.522	**-0.753**	0.400	*0.414*
B546		Black-faced Woodswallow	-0.383	0.040	**0.923**	*0.407*
B229		Black Kite	-0.252	**-0.758**	0.602	*0.401*
B543		White-breasted Woodswallow	**-0.879**	-0.061	0.474	*0.397*
B866		Chirruping Wedgebill*	-0.684	-0.013	**0.730**	*0.380*
B635		Yellow-throated Miner	**-0.744**	0.138	0.654	*0.377*
B297		Blue Bonnet	-0.664	-0.168	**0.728**	*0.376*
B424		Black-faced Cuckoo-shrike	-0.639	-0.468	0.610	*0.368*
B570		Red-browed Pardalote	-0.427	-0.542	**0.724**	*0.360*
B647	AusPip	Australasian Pipit	0.453	-0.657	-0.602	*0.336*
B342		Horsfield's Bronze-Cuckoo*	-0.100	**-0.855**	0.509	*0.334*
B515	EyGrwr	Eyrean Grasswren	0.418	-0.644	0.640	*0.311*

Many more species than those shown in Figure 18 had a strong association with riparian environments, and the additional species are given in Table 23 (bolded values for PCS1). Other species than those depicted in Figure 18 that became more prevalent in 2016 are indicated in Table 23 by the bolded values for PCS2, and included Black Kite, Horsfield's Bronze-Cuckoo and Fairy Martin. The species with large positive values for PCS3 have preferences for more open environments than those found in the regions' riparian zones, with the Blue Bonnet and Red-browed Pardalote favouring floodplains and dune margins with a scattering of Coolibah, while the Chirruping Wedgebill favours scrubby habitats on the floodplain (with Lignum +/- Old Man Saltbush often providing the shrub cover in the region), a habitat also favoured by both species of fairy-wren and their brood parasite, the Horsfield's Bronze-Cuckoo. Species with middling to large positive values on the third axis also tended to be more abundant and frequent on Kalamurina sites, as shown by its affinity with PCS3 in Table 24.

Changes in bird assemblage composition over the survey period appeared to be quite directional as seen in the ordered variation in mean position of sites along PCS axis 2 (Table 24), with the mean PCS2 value for 2015 observations being about midway (*ca* 0) between those for 2014 (+0.7) and 2016 (-0.7). Given the short run of years, this result should not be construed to suggest that directed (linear) change in bird community composition would be expected to continue were future surveys conducted. The other main point illustrated in Table 24 is the lack of a strong river-longitudinal (geographically linear) trend in the landbird compositional data – neither by property nor by management zone is there any indication that sites high in the system (e.g. those on Pandie Pandie) lie at opposite ends of a compositional gradient from sites lowest in the system (i.e. Kalamurina). For properties, the biggest spread in mean values occurs along axis PCS3, and Kalamurina and Clifton Hills lie at either end of this spread. For management zone (along PCS2), the Goyder Lagoon and Diamantina reaches lie at opposite ends of this gradient in landbird compositional change. This absence of an obvious longitudinal signal refutes one of the main expectations voiced at the outset of the study, and the result is even more surprising given the knowledge that two species pairs are largely confined to upper (Red-rumped Parrot, White-browed Babbler) and lower parts (Blue Bonnet, Chestnut-crowned Babbler) of the region. Additionally two species were confined to central and lower parts, namely Chirruping Wedgebill and Cinnamon Quail-thrush, while the Grey Shrike-thrush was absent from the middle sections of the Warburton River and further south.

Table 24 Centroids (mean position) of sites belonging to the categories (survey design factors) of year, habitat, property identity and management zone. Ignoring the two observations at sites constituting gibber habitat (outliers in the ordination), for each factor the PCS axis values encompassing the greatest spread of groups are bolded

Year	**PCS1**	**PCS2**	**PCS3**
2014	-0.174	**0.690**	0.040
2015	0.264	**0.060**	-0.273
2016	-0.147	**-0.699**	0.279
Habitat			
Dune	**0.990**	0.019	0.510
Floodplain	**0.522**	0.108	-0.197
Gibber	**2.015**	-0.224	-2.364
Riparian	**-0.908**	-0.087	0.019
Property			
Clifton Hills	0.266	-0.230	**-0.278**
Cowarie	-0.126	0.310	**-0.104**
Kalamurina	-0.339	-0.170	**0.600**
Pandie Pandie	-0.183	0.340	**0.288**

Year	PCS1	PCS2	PCS3
Management Zone			
Diamantina	-0.128	**0.343**	-0.015
Eyre	0.353	**0.109**	0.317
Goyder Lagoon	0.500	**-0.695**	-0.388
Warburton-Kallakoopah	-0.161	**0.072**	0.139

Constrained ordination tests of the influence of the four design factors in shaping bird assemblage composition, undertaken in cca with the 138 observations used for the above NMDS ordination were all significant, either as single tests or in combination (Table 25). It is stressed there is a risk that the significance levels may be inflated due to the correlated structures inherent in the survey design, but the results appeared reasonably robust (see below). With all four terms included in the CCA, the habitat classification exerted the strongest influence on bird species' distribution across sites, followed by year of survey (Table 25a). The effects of property identity had the weakest influence on assemblage composition (lowest F statistic), but this term was still included, in combination, at $P < 0.001$. These statistical results are mirrored in the unconstrained ordination results summarised in Table 24, where habitat effects are loaded most strongly onto the first axis and have the greatest range in scores, while property effects were relegated to the third axis and had the lowest spread of scores among the four factors. Spread of sites by year on the second (PCS2) axis was greater than that by management zone (Table 24).

One of the potentially correlated error structures that could readily be accounted for within cca was to restricted permutations for significance testing to observations belonging to the same site (similar effect to specifying Site as a random effect in earlier REML models). The second set of results in Table 25a show that habitat and year were still highly significant but that only property or management zone could then be additionally fitted as a highly significant term ($P = 0.004$, for both). Once either property or management zone were included in the cca model, the other's effect was only weakly significant ($P < 0.05$) or marginal ($P < 0.1$), i.e. there was a moderate amount of overlap (covariance) in their effects as might be expected (Table 25a). Removal of the repeated measures component was achieved by averaging the NMDS ordination scores for each unique subsite ($n = 81$, with the two gibber observations removed). This removed any correlation due to multiple visits (across years) to the same subsite, and capscale analyses (using Euclidean distances) preserved the structure of the NMDS averaged scores. The effect of habitat was again highly influential in capscale models of the reduced dataset, explaining 39% of the variance in spread of sites in three dimensions (capscale analysis: Table 25b). With no constraints to permutation to assess significance, the three factors (habitat, property and management zone) could be fitted in combination, although the latter two terms were included at $P < 0.05$ ($P1$ values in Table 25b). A capscale model with habitat as the only independent variable, and in which levels of significance were obtained by constraining permutations of subsites within management zone, again returned a low probability ($P < 0.001$). To test the strength and significance of property and management zone on the reduced dataset, capscale analysis of these two factors in combination was undertaken, but with permutations for significance testing only permitted within subsites in the same habitat class and which, therefore, largely eliminated any correlated errors due to site location. The influence of management zone on assemblage composition was slightly greater than that of property (Table 25b: $P3$ values; $P < 0.05$) when fitted in combination, but both factors were highly significant in isolation ($P < 0.001$), confirming they shared much information content.

Table 25 Results of a) cca tests of the factors year, habitat, property and management zone on the raw data of 138 transect observations of 64 landbird species, and b) capscale tests of habitat, property and management zone on the NMDS ordination scores (PCS1-3) averaged across years for 81 unique subsites, under different permutation models for assessing levels of significance: *P*1- unconstrained (free) permutations across all observations; *P*2- shuffling of subsite observations only permitted within sites; *P*3- shuffling within sites in cca tests and within habitat classes in capscale test. Chi-square (ChiSq) partitioning in cca is the equivalent of variance partitioning in capscale analyses. All tests assessed the partial effect of the focal term, in combination with other factors in the model

a) cca, anova by marginal effects of terms, *n* = 138				**free**	**block = Site**	
Factor	**Df**	**ChiSq**	***F***	***P*1**	***P*2**	***P*3**
YrF	2	0.138	2.843	0.001	0.001	
HabMaj	2	0.233	4.796	0.001	0.001	
Prop	3	0.121	1.662	0.001	0.031	0.004
MGZ3	2	0.096	1.968	0.001	0.093	0.004
Residual	126	3.058				
b) capscale, anova by marginal effects of terms, *n* = 81				**free**	**Site**	**HabMaj**
Factor	**Df**	**Var**	***F***	***P*1**	***P*2**	***P*3**
HabMaj	2	0.696	17.004	0.001	0.001	
Prop	3	0.130	2.121	0.027	0.001	0.021
MGZ3	2	0.110	2.680	0.018	0.001	0.036
Residual	73	1.493				

* two separate cca models and one capscale model used for these tests, and so residual d.f.s, *F* values and unexplained variance values will differ from those presented which relate to models tested under *P*1 and *P*2; these cca models included either Prop or MCZ3 as the third term (dropping the other), while the capscale model dropped HabMaj (used as the blocking factor) and tested the partial effects of property and management zone

4 Discussion

Our study is the first to document in a quantitative and systematic manner the birdlife of the Diamantina and Warburton rivers in South Australia. In particular, we have described the distribution, abundance, diversity and composition of bird communities in relation to various factors, such as a) longitudinal position along the river system, b) vegetation and habitat variables spread across the floodplains from the riparian river margins to the fringing dunefield environments, and c) prevailing climatic conditions. The last factor, antecedent and current climatic conditions, proved to be a major constraint (drought, uneven spatial distribution of limited rainfall events) to documenting the full diversity and abundance of a boom-bust ecosystem that typifies riverine, wetland and floodplain environments in the Lake Eyre Basin (Kingsford *et al.* 1999a; Roshier *et al.* 2001a, 2002; Reid 2010; Reid *et al.* 2010), given the absence of widespread flooding over the course of the study. However, a critically important role of Lake Eyre Basin rivers in dry times – provision of drought refuge habitat and food resources – was amenable to study due to the prevailing conditions. Reid (2008, 2010) has highlighted the importance of riparian environments in arid parts of the Lake Eyre Basin to birds in times of drought, and it is highly likely that several of the notable bird discoveries made during this project were further examples of bird species capitalising on the relative abundance of food resources (and moisture) in otherwise dry environments. Although impossible to prove, the unusual occurrences of Brown Quail, Spotted Bowerbird, Painted Honeyeater, Golden Whistler and Olive-backed Oriole (Bond & Reid 2016) along the Diamantina and Warburton rivers on Pandie Pandie, Clifton Hills and Cowarie stations in 2015, at the height of the drought across inland Australia, were thought to reflect the pull of these rivers at such times. Despite pervasive drought conditions regionally, a combination of factors – water-shedding local rains in the study area and limited flooding into the region from Queensland flows in the Diamantina River over summer-autumn 2015 – had freshened waterholes and fringing environments ahead of the 2015 survey.

Perhaps the most surprising result of the study was the absence of a clear longitudinal gradient in the diversity and composition of bird communities in the region. We had expected the species richness of bird communities to decline with distance downstream from the Queensland border to the lower reaches of the Warburton River on Kalamurina Sanctuary. Formally, we expected to find a (negative) linear correlation between richness and distance downstream. Also, given prior knowledge of limits to the distribution (or the regular occurrence) of several bird species within the region, particularly Red-rumped Parrot, Blue Bonnet, White-browed Babbler, Chestnut-crowned Babbler and Chirruping Wedgebill, we also expected to discern linear shifts in assemblage composition with distance downstream. The hydrological gradient (declining discharge) and rainfall gradient (albeit relatively weak), with both mean annual streamflow and mean annual rainfall decreasing from Birdsville to Lake Eyre, and the results of the recent Cooper Creek study (Reid & Gillen 2013) all pointed to these expectations. However, ordered (linear) changes in landbird richness and composition were not observed. Within riparian bird communities, higher richness and abundance occurred at either end of the study area (at sites on Pandie Pandie Station and Kalamurina Sanctuary), with maximum diversity observed on Kalamurina at the bottom of the system (Figure 10). Similarly, the composition of riparian bird assemblages were most divergent in central portions of the study area, in the Goyder Lagoon complex. This second result can be illustrated with a partial constrained ordination, where the effects of habitat and year of survey have been partialled out (Figure 19). Sites in Goyder Lagoon do not lie between management zones Diamantina and Warburton-Kallakoopah.

Of the numerous habitat attributes measured at the 84 subsites, several were found to be pre-eminent in their control of bird species richness and distribution in the study area. Presence and cover of Coolibah had the strongest influence on the composition of landbird assemblages (MVA results). Almost as potent in shaping bird assemblage composition was Broughton Willow. REML modelling demonstrated that these two plants, in reverse order, were also the best predictors of bird species richness across sites – from REML models, including one plant variable at a time, in combination with property identity and year (Table 26). We have previously noted that Coolibah dropped out of multi-variable REML models when habitat was included as a fixed effect, and so it is important to emphasise here its dominating influence over the structure and composition of bird communities in the region. The next most important plant in terms of its predictive and structuring power was Lignum (Table 26). Other important floristic variables that could routinely be included in multi-variable REML models were the composite variables of mistletoe ('Mist'), the category combining Ruby and Spiny saltbushes ('Ench_Ein'), and number of small tree species ('NSTsp'). The two most influential (non-floristic) habitat variables shaping diversity and composition of bird communities in the region were the amounts of ground litter and fallen large dead timber, ranked third and fourth in both sets of analyses (Table 26). Abiotic variables measuring the amount of hollows (positively) and bare ground (negatively) were the next highest ranked predictors of bird species richness (ninth and seventh, respectively) and assemblage composition (ranked fifth and seventh, respectively). Collectively, these nine variables allow us to build a picture of ideal riparian habitat for birds along the rivers and channels in the study area. Structural diversity is the key, with large spreading Coolibahs physically dominating the environment, and with dense stands of Broughton Willow and other small tree species, and with plenty of mistletoe on the long-lived trees and shrubs. Dense stands of Lignum provide cover for understorey birds as well as playing a crucial role in maintaining bank stability, and there is plenty of Ruby Saltbush and/or Spiny Saltbush growing under the trees, providing fruit, seed and other resources. A deep litter layer is extensive in the ideal riparian habitat for birds, and large amounts of fallen timber and standing dead trees provide shelter and breeding opportunities (e.g. hollows) for many bird species as well as contributing to nutrient and carbon cycles.

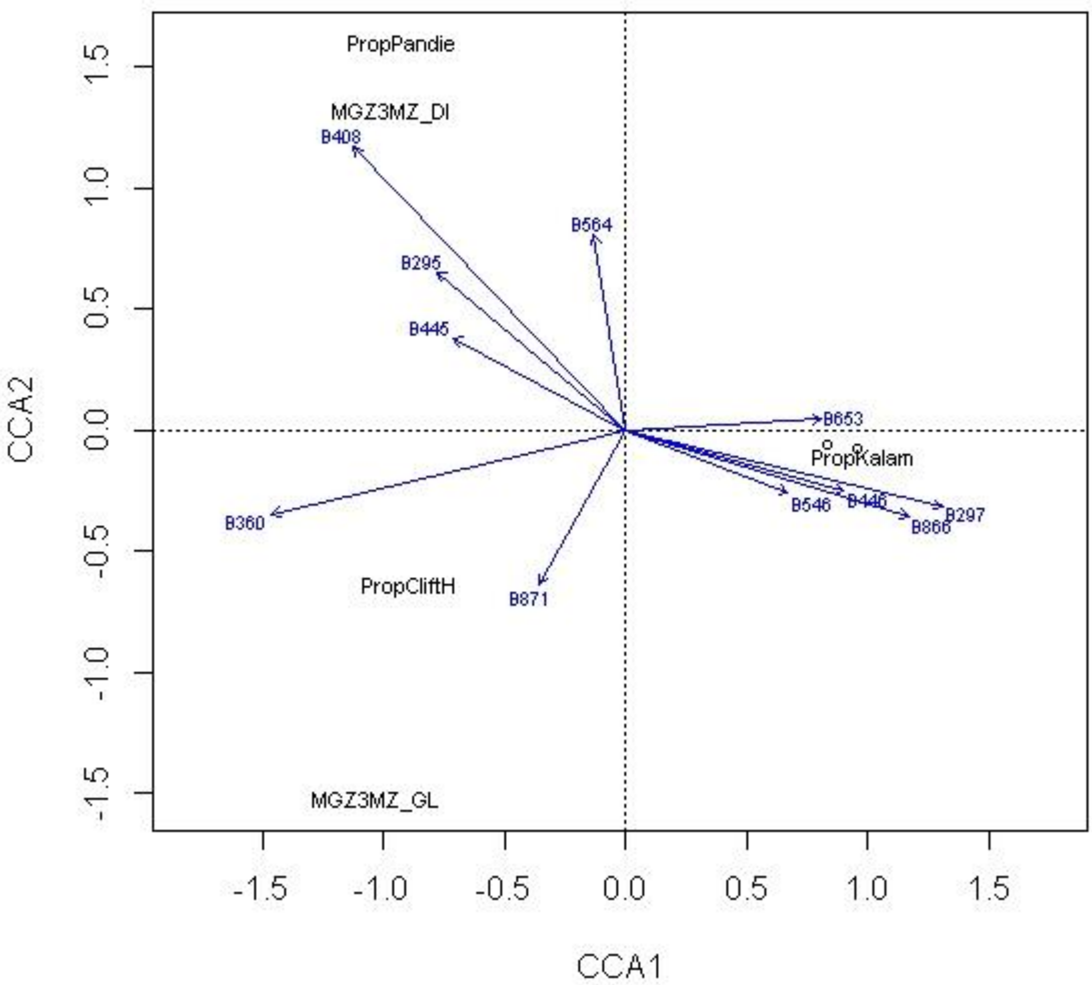


Figure 19 Partial (effects of year and habitat removed) constrained CCA showing effects of property identity and management zone, and the species significantly associated with these factors (only species at *P* <= 0.002 plotted)

Table 26 lists 22 habitat variables, 21 of which were common to both sets of analyses, out of a pool of 35 variables having more than a few occurrences at 84 subsites. Despite the similarity of the lists for the first nine or so variables in terms of ranked strength, the overall correlation between the two sets of ranks was only modest (Spearman rank test: *rho* = 0.58; $P < 0.007$). Part of the mismatching between the lists arises from the PCC analyses applying equally to bird assemblages in all environments studied across the region while simple REML models of species richness, by default, were focussed on correlations between habitat variables and riparian bird assemblages, since these environments supported the most diverse communities. Hence, while Umbrella Wattle (Ac_lig) and Sandhill Canegrass (Zyg_para) were highly ranked (sixth and ninth, respectively) in the PCC analysis, given their strong associations with bird species in sand dune environments, these plants, in isolation, were poor predictors of bird species richness (REML models). However, it is worth noting that in more complex REML models (e.g. see Table 18), these structurally important plants in dune environments became potent predictors of higher numbers of bird species.

Table 26 Correlative strength of the most influential individual plant and habitat variables in relation to bird species richness (REML models) and assemblage composition (PCC), for comparison. The first 15 variables are listed in rank order of the multiple correlation coefficient (R_m) from PCC (bolded values indicate P = 0.001); the last seven variables were in the top 18 ranks from REML models (bolded values indicate P <= 0.005). All REML models contained the Site and subsite terms as random effects and YrF and Prop as fixed effects, with the effect of plant and habitat variables tested one at a time (n = 142). PCC results are from Table 22, relating to the NMDS ordination shown in Figure 15 (n = 138)

Variable	REML Rank	t_value	PCC Rank	R_m
Cool	2	**8.60**	1	**0.835**
Ac_sali	1	**11.40**	2	**0.745**
litter	3	**7.94**	3	**0.660**
FallLgDT	4	**6.46**	4	**0.642**
hollows	9	**4.74**	5	**0.559**
Ac_lig	23	-1.93	6	**0.503**
baregrnd	7	**-5.32**	7	**0.503**
Lignum	5	**5.69**	8	**0.503**
Zyg_para	20	-2.05	9	**0.487**
Ench_Ein	6	**5.67**	10	**0.486**
Ac_sten	18	**2.82**	11	**0.444**
ephems	32	-0.21	12	**0.433**
Am_preis	10	**4.06**	13	**0.418**
FallSmDT	12	**3.41**	14	**0.411**
grasses	29	-1.25	15	**0.409**
Mistle	8	**4.94**	N/A	-
Sant_lan	11	**3.81**	16	**0.380**
Sen_cunn	13	**3.25**	32	0.256
sawn	14	**3.10**	28	0.279
Er_bign	15	**3.05**	23	**0.351**
Lys_exoc	16	**3.01**	29	0.270
Bauh	17	**2.88**	25	0.311

Spatial patchiness of habitats and habitat elements was not measured in this study, but given the dynamic nature of these river systems, subject to pulses of high-energy streamflow and intense rain storms, the linear strands of riparian vegetation are naturally patchy, and it is likely that spatial heterogeneity also contributes to greater bird diversity and habitat condition at scales slightly larger than the 500-m transects used. Similarly, the width of the riparian habitat varies greatly depending on local hydrology, geomorphology and perhaps, in parts, European history and land-use, and it is likely that broader swathes of dense riparian vegetation, usually associated with depositional environments (e.g. inside meander loops), will support richer riparian bird communities. Width of riparian stands at transect subsites could be measured from satellite imagery retrospectively to test this assertion.

4.1 Importance of Mistletoes in Riparian Vegetation

Three species of mistletoe were observed on transects, and their presence and rank abundance were found to contribute significantly to greater bird abundance and diversity, results consistent with studies elsewhere in Australia (Watson 2002) and the world (Watson 2001). The most abundant mistletoe species, *Amyema preissii* or Wire-leaf Mistletoe, grew commonly on Broughton Willow, and was occasionally noted on River Cooba, Lignum, and Umbrella Wattle (*A. ligulata*). Also widespread was the Harlequin Mistletoe, *Lysiana exocarpi*, commonly growing on Plumbush, not infrequently on River Cooba, and occasionally on Lignum, Whitewood, and Broughton Willow. *Diplatia grandibractea* was noted sparingly on Coolibah. The abundance of mistletoes in the riparian vegetation, particularly, provides important food resources for birds, in terms of nectar and fruit, and allowed the occurrence of Painted Honeyeater, an obligate mistletoe fruit specialist, in the region in May 2015. Mistletoes also play important roles in nutrient cycling and provide local hotspots of nutrient concentration, and Watson (2001) argued they have a keystone role in ecosystem functioning, supported by a subsequent landscape-scaled removal experiment (Watson *et al.* 2012).

This study revealed that the presence and greater cover of mistletoe increase a bird community's diversity and abundance, while also contributing significantly to community assembly. Two bird species frequently observed in riparian vegetation throughout the study area were Mistletoebird (obligate feeder on mistletoe berries) and Spiny-cheeked Honeyeater which also feeds extensively on the fruit of mistletoe (Reid 1990). As well as mistletoes, several other plants are important fruit sources in riparian vegetation, with Plumbush the most significant of these. In May 2015 the Spotted Bowerbird, an obligate frugivore, was observed in an area ('DSplit' Waterhole) of dense and abundantly fruiting Plumbush, although the bird was not observed feeding. Ruby saltbush, a common subshrub under Coolibahs, and widespread through a range of environments, is also an important source of fruit and seeds for a wide range of birds and other animals (e.g. Barker & Vestjens 1989, 1990).

4.2 Landbird Assemblages and Summary of Distribution and Diversity Patterns

The notion of discrete bird communities occupying specific habitats is an abstract concept, and the closest that the concept was realised in this study was at the scale of whole-of-site, where there was a good matching between the three main management zones surveyed – Diamantina, Goyder Lagoon, and Warburton-Kallakoopah – and the similarity of birdlists among sites within each zone (e.g. see Figure 7). At this spatial scale, over which the birds of various sampled habitats were combined, the avifaunas of the three regions, despite sharing most species, were sufficiently distinctive for observations within each zone to cluster together (as seen in the dendrogram: Figure 6). Waterbirds dominated the assemblages in Goyder Lagoon, despite limited availability of actual wetland habitat, to a greater degree than in the two other zones. The site birdlists from the Goyder Lagoon region were sufficiently distinctive to set this zone apart from the other two, i.e. The Diamantina and Warburton-Kallakoopah sites had more species in common than either did with Goyder Lagoon sites, thus negating a primary hypothesis articulated at the start of the study (of longitudinally structured bird communities). Even with the waterbird species removed, in subsequent analyses, longitudinal structuring of habitat-specific bird assemblages was still not evident. Such is the biogeographic power of the size, unique landforms and vegetation communities (and dynamics, being largely vegetated with short-lived species) of Goyder Lagoon, that it disrupts and shapes the distribution of bird species across the study area to such an extent that these results were obtained. As well as being a vast and magnificent wetland complex during, and on the recession phase of, big floods, supporting hundreds of thousands of breeding waterbirds (Reid & Jaensch 2004; Reid *et al.* 2009), and providing core habitat for a small number of passerine species (notably Grey Grasswren), it acts as a partial barrier to the distribution of several sedentary landbirds. Most of these have been identified previously – Red-rumped Parrot, Blue Bonnet, White-browed Babbler, Chestnut-crowned Babbler and Chirruping Wedgebill, but also Thick-billed Grasswren, Cinnamon Quail-thrush, Grey Shrike-thrush and possibly Southern Whiteface, of which the last was only seen along the Warburton River during the study.

As well as the compositional distinctiveness of the avifauna in each management zone, species richness (landbirds and waterbirds combined) varied systematically across the three regions (Table 5; Figure 5), a result driven by the greater variety of waterbirds at sites in Goyder Lagoon. Sites in Goyder Lagoon had significantly more of all bird and waterbird species while the numbers of landbird species did not vary significantly between zones (Table 5, Figure 21).

The riparian bird communities along the major channels in the Diamantina and Warburton-Kallakoopah zones were distinctive for their high species richness and component species, and Table 13 identifies the species that were significant indicators of riparian bird assemblages. Of the 64 landbird species observed at least twice on transects at subsites over the course of the survey, fully 37 of them occurred more frequently and at greater abundance in riparian habitat than in dunes and on the floodplain. Broadly, riparian bird communities along the length of the system visited were dominated by pigeons (Peaceful Dove, Crested Pigeon), cockatoos (Galah) and the larger parrots, kites, and many passerine species, particularly Variegated Fairy-wren, White-plumed Honeyeater, Spiny-cheeked Honeyeater, Yellow-throated Miner, Willie Wagtail, Tree Martin, Australian Raven, Mistletoebird, Magpie-lark and White-breasted Woodswallow (see Table 27Table 4 for full list). Bird communities in the study area were not as species rich as those along Cooper Creek (Reid & Gillen 2013), but further surveys after a good year would be required to make a proper comparison. Species missing from the Diamantina-Warburton system included Barking Owl, Australian Ringneck, Brown Treecreeper, Chestnut-rumped Thornbill, Black-chinned (Golden-backed race) Honeyeater and Jacky Winter.

While there were a few species characteristic of sand dune habitat identified during the study – Pallid Cuckoo, Eyrean Grasswren, White-winged Fairy-wren and Singing Honeyeater (from Table 13) – the first is an episodic nomad and the grasswren is confined to dunes with a good cover of Sandhill Canegrass rather than dunes generally. Other species frequently observed along dune transects included Crested Pigeon, Horsfield's Bronze-Cuckoo, White-backed Swallow, Fairy Martin, Willie Wagtail, Red-capped Robin, Black-faced Woodswallow, Red-browed Pardalote and, at times in great abundance, the Zebra Finch. Indicator Species Analysis did not find any species diagnostically characteristic of the broad floodplain class of habitats, perhaps because of the variability within the category. However, many species were regularly observed at floodplain sites – including Diamond Dove, Red-backed Kingfisher, White-plumed Honeyeater, Crimson Chat, two species of pardalote, Red-capped Robin, Rufous Whistler, both fairy-wren species, Willie Wagtail, Black-faced Woodswallow, Zebra Finch and, in the south, Chestnut-crowned Babbler and Chirruping Wedgebill – although for many their likelihood of occurrence depended on actual habitat particulars. It is apparent from the above lists that some species, e.g. Crested Pigeon, Variegated Fairy-wren, White-plumed Honeyeater, Willie Wagtail, Black-faced Woodswallow, White-backed Swallow and Zebra Finch, ranged widely across all habitats from the channels to fringing dunes (see Table 27).

The composition of bird communities changes dramatically over time due to the episodic nature of rainfall and flooding events. In this study, the occurrence and/or abundance of many species varied greatly depending on local and regional conditions. Species which showed the greatest fluctuations in distribution and abundance over the three years were Diamond Dove, Whistling and Black Kite (both absent from the Warburton River in 2014), Nankeen Kestrel, Little Corella, Budgerigar, cuckoos, Red-backed Kingfisher, Crimson Chat, Masked and White-browed Woodswallow, Fairy Martin and Zebra Finch. Because boom conditions were not experienced during surveys, several other species known to be widely nomadic through inland Australia were seen too infrequently to be included in the above list, namely Little Button-quail, Brown Falcon, Cockatiel, Pied Honeyeater, White-winged Triller, Brown and Rufous Songlark, and Little Crow, but could be predicted to have become abundant in 2016, following the drought-breaking rains we experienced in May. Several of these species, e.g. Cockatiel, Rufous Songlark and White-winged Triller, had begun moving into the study area by the end of the third survey. Bird communities in the region are dynamic, and a longer study than ours would be needed to capture the highs of population booms – we have probably documented a typical 'bust' situation.

Table 27 Species most frequently observed in the three main habitats on a) riparian, b) floodplain, and c) sand dune transects. Percent frequency (from 61, 51 and 26 counts, respectively), and the mean density (calculated only when the species was detected, i.e. excluding zeros: ha^{-1}) in the habitat are presented

a) Riparian			b) Floodplain			c) Dune		
English Name	**%Freq**	**AvDen**	**English Name**	**%Freq**	**AvDen**	**English Name**	**%Freq**	**AvDen**
White-plumed Honeyeater	**100.00%**	**3.68**	**White-plumed Honeyeater**	**80.39%**	**1.16**	**White-winged Fairy-wren**	**80.77%**	**1.14**
Willie Wagtail	**91.80%**	**0.75**	**Willie Wagtail**	**62.75%**	**0.37**	**White-plumed Honeyeater**	**69.23%**	**0.52**
Crested Pigeon	**83.61%**	**0.63**	**Zebra Finch**	**54.90%**	**2.16**	**Zebra Finch**	**69.23%**	**4.28**
Galah	**72.13%**	**0.82**	**Crested Pigeon**	**50.98%**	**0.37**	**White-backed Swallow**	**65.38%**	**0.45**
White-backed Swallow	**72.13%**	**0.45**	**Diamond Dove**	**41.18%**	**0.61**	**Willie Wagtail**	**61.54%**	**0.48**
Australian Raven	**70.49%**	**0.29**	**White-backed Swallow**	**41.18%**	**0.39**	**Black-faced Woodswallow**	**50.00%**	**0.52**
Tree Martin	**68.85%**	**1.53**	**Variegated Fairy-wren**	**41.18%**	**0.82**	**Crested Pigeon**	**46.15%**	**0.44**
Magpie-lark	**63.93%**	**0.36**	Galah	37.25%	0.73	Variegated Fairy-wren	30.77%	0.71
Mistletoebird	**62.30%**	**0.52**	White-winged Fairy-wren	37.25%	0.82	Fairy Martin	26.92%	0.86
Zebra Finch	**55.74%**	**1.72**	Black-faced Woodswallow	37.25%	0.49	Red-browed Pardalote	26.92%	0.16
Spiny-cheeked Honeyeater	**54.10%**	**0.60**	Tree Martin	33.33%	0.71	Diamond Dove	23.08%	0.62
Diamond Dove	**52.46%**	**1.13**	Blue Bonnet	29.41%	0.49	Black Kite	23.08%	0.25
Variegated Fairy-wren	**52.46%**	**1.06**	Budgerigar	25.49%	1.71	Horsfield's Bronze-Cuckoo	23.08%	0.47
Peaceful Dove	**50.82%**	**0.39**	Chirruping Wedgebill	21.57%	0.21			
Whistling Kite	**47.54%**	**0.28**	Red-backed Kingfisher	17.65%	0.17			
White-breasted Woodswallow	**45.90%**	**0.51**	Horsfield's Bronze-Cuckoo	17.65%	0.17			
Black-faced Woodswallow	42.62%	0.58	Rufous Whistler	17.65%	0.18			
Fairy Martin	40.98%	1.44	Red-browed Pardalote	17.65%	0.18			
Yellow-throated Miner	40.98%	0.42	Fairy Martin	15.69%	0.74			
Chirruping Wedgebill	39.34%	0.39	Red-capped Robin	15.69%	0.50			
Little Corella	37.70%	0.90	Chestnut-crowned Babbler	15.69%	0.25			
Blue Bonnet	37.70%	0.43	White-breasted Woodswallow	15.69%	0.26			

a) Riparian			b) Floodplain			c) Dune		
English Name	**%Freq**	**AvDen**	**English Name**	**%Freq**	**AvDen**	**English Name**	**%Freq**	**AvDen**
Grey Shrike-thrush	37.70%	0.60	Yellow-throated Miner	15.69%	0.18			
Black-faced Cuckoo-shrike	37.70%	0.29						
Budgerigar	36.07%	2.07						
Red-backed Kingfisher	29.51%	0.21						
Black Kite	26.23%	0.63						
Chestnut-crowned Babbler	26.23%	0.48						
Red-browed Pardalote	26.23%	0.16						
Horsfield's Bronze-Cuckoo	24.59%	0.18						
Red-rumped Parrot	18.03%	0.41						

The absence of Whistling and Black Kite from sites along the Warburton River in 2014 was intriguing, due no doubt to the combination of drought and the hypersaline nature of the few residual pools of water in the river. Indeed, Black Kites were not recorded centrally along any transect in 2014 and were scarce over the entire study area (recorded at three sites). They were still scarce in 2015 (three transects only, seven sites), but were abundant and widespread in 2016 being seen at all sites. While the Black Kite is known to be a highly mobile species (Marchant & Higgins 1993), in inland Australia there are thought to be sedentary individuals of Whistling Kite augmented by migrating birds from the south (Marchant & Higgins 1993). Clearly the data gathered in this study do not support this assertion, as Whistling Kites had vacated the Warburton River in 2014. Whistling Kites were present at all sites between Goyder Lagoon Waterhole and Pandie Pandie Homestead in 2014. In 2015, presumably in response to the fresh inflows along the Warburton and Kallakoopah rivers, Whistling Kites were present at the four sites visited on Cowarie Station (and all sites surveyed in that year). They were again widespread along the length of the river system in 2016.

As shown in Figures 3.7-3.9 and Table 10, landbird community abundance in riparian habitat was about double that in floodplain and dune habitats, while species richness at riparian sites (*ca* 17) averaged almost double that of dunes and floodplain (*ca* 9). While these averages mask considerable variation due to year, management zone and property identity, they capture the dominant trend of differences by broad class of habitat. The few observations made in gibber habitat, at Goyder Lagoon Waterhole and Stony Point Waterhole, indicate that in dry times gibber environments lie at the bottom of this gradient in richness and abundance (few species at low abundance). Landbird abundances generally doubled between 2014 and 2016, with dune sites having the greatest capacity for increase, perhaps largely due to a relatively few species such as Diamond Dove, Little Corella, Zebra Finch, Masked Woodswallow and Fairy Martin. However, many species showed steady, gently increasing trends over the three years, suggesting that conditions materially improved over the study.

Landbird richness and abundance were consistently greater at sites on Kalamurina than the other three properties. Only in the riparian zone did one property, Pandie Pandie, have comparable diversity (but still slightly lower values than for Kalamurina). It is highly probable that the change in management and land use about eight years ago, from cattle station to wildlife sanctuary, contributed substantially to this result, but slightly higher rainfall in the southern parts of the study area in the period leading up to surveys in 2014 and 2016 may also have contributed. Further comparative studies on Cowarie and Kalamurina would be required to account for the possible effects of variations in local rainfall totals. Ignoring potential climatic causes, the greater ground and shrub cover in the vegetation on Kalamurina compared with the three cattle stations in 2014 was most apparent and probably a major reason for the higher levels of landbird richness and abundance. The 'best' multi-variable REML model obtained for species richness included the following habitat variables as positive correlates – litter, Ench_Ein, Zyg_para, Sen_cunn, NSTsp (Table 18) – i.e. four ground and low shrub layer attributes (litter, Ruby and Spiny saltbush cover, cover of Sandhill Canegrass, and cover of the bushy daisy, *Senecio lanibracteus*), and the number of small tree species. The last variable was probably included on the strength of high species richness observed at riparian sites on the Diamantina River ('DSPlit', Double Bluff and 'Pandie' waterholes), but the other four variables relate directly to the observations of greater shrub and ground cover on Kalamurina. It would be interesting to investigate whether the riparian assemblages along the Diamantina River have proportionately more canopy-dwelling species than those on Kalamurina, as a consequence of the perceived habitat differences, of more tall shrubs and small trees upstream along the Diamantina River versus greater low shrub and ground cover and habitat complexity along the Warburton River on Kalamurina.

The high landbird species counts in riparian habitats at both ends of the system (Pandie Pandie and Kalamurina) explain the previously described pattern of the even distribution of all birds' site-scale richness across the three main management zones, i.e. of landbirds and waterbirds combined. Because birds in riparian habitat numerically dominate site-scaled assemblages, the fewer waterbirds generally recorded at sites along the Diamantina and Warburton rivers were compensated for by the higher riparian landbird species richness at either end of the system. In fact, although significantly higher landbird species richness was found on the Kalamurina Sanctuary than elsewhere, closer scrutiny of the species richness data revealed that the two most southerly sites on Cowarie Station, namely Stony Point Waterhole and Cowarie Crossing, had comparable levels of riparian species richness as riparian sites on Kalamurina (Figure 20). When sites on the main channels of the Diamantina-Warburton-Kallakoopah system were plotted in rank order from upstream (Pandie Pandie) to downstream (Poonarunna Bore), the trends in riparian species richness displayed several patterns. First, the three uppermost sites – all on Pandie Pandie (*ca* 19 spp) – had about four landbird species more, on average, than Andrewilla, Yammakira and Koonchera waterholes. Second, the isolated Goyder Lagoon Waterhole (nine species, average of three transect counts), was quite depauperate in riparian landbirds compared with other sites. Third, the upper Warburton and upper Kallakoopah sites had similar richness to, just one or two species fewer than, the upper Goyder Lagoon sites. Finally, the seven middle to lower Warburton sites, from Stony Point Waterhole downstream, had significantly higher species richness (> 20 species), with some variability. Two simple trends are plotted on the data points in Figure 20, and we see that a simple quadratic curve accounts for almost 50% of the variance, a much better fit than the straight-line trend.

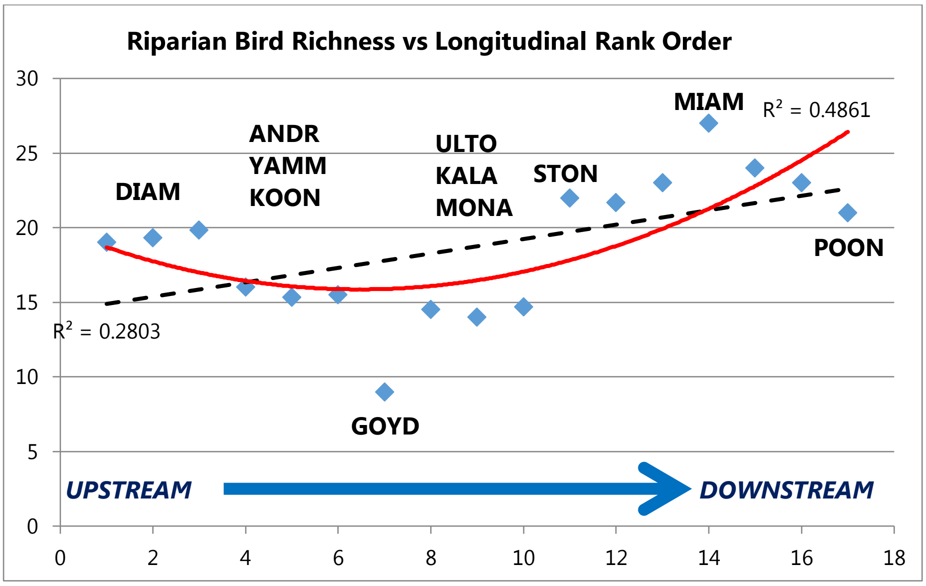


Figure 20 Plot of riparian landbird richness against rank order in longitudinal position of sites on the main channels of the Diamantina, Warburton and Kallakoopah rivers. Two observations made after the major rains in May 2016 were discarded; otherwise the mean richness (from one to six observations) was calculated for each site

There is evidence, perhaps, in the right-hand end of the plot in Figure 20 for the expected decline in species richness with further distance downstream, but more observations lower in the system would be required to evaluate this proposition. Reid & Gillen (2013) attributed the decline in riparian landbird species richness along the length of Cooper Creek in South Australia with the decline in abundance and cover of Coolibahs, particularly in the lower, saline parts of that river (see also Badman 1989). The bottom end of the Cooper receives very few regional flows (Kotwicki 1986), and so the thinning out of Coolibahs and higher salinity, in part, ultimately derive from the much smaller and infrequent flows. Given that regional flows in the Georgina-Diamantina catchment reach Lake Eyre roughly one year in two, the bottom end of the Warburton River may have denser stands of Coolibah than equivalent reaches on the Cooper, and so the loss of riparian bird species between Poonarunna and the estuary around Lake Eyre North may not be as extreme. However, higher up the system there was some support for the role that long-term mean annual discharge has in structuring bird communities in the study area. Costelloe (2017; see project companion report) has shown that roughly equal amounts of the Diamantina River's flows are carried down the two major feeder channels from the disjunction at 'DSplit' Waterhole, i.e. **half** of the discharge flows along each of the Yammakira and Andrewilla channels (under bankfull or lower-flow circumstances). Accordingly we could expect bird species richness to be higher at the three Pandie Pandie sites than at Yammakira and Andrewilla waterholes. A *t*-test, under the assumption of equal variances and ignoring the repeated-measures component, upheld this expectation – mean riparian landbird richness on Pandie Pandie sites (19.8) averaged over four more species (t_{14} = 2.95, P < 0.05; Fig. 2.20). The overall trends in species richness and assemblage composition across property and management zone and by year and habitat are shown in Figure 21.

Summary of Trends in Avian Richness, Abundance and Compositional Change by Survey Design Factors

	WHOLE OF SITE				SUBSITE	
	All birds		Waterbirds	Landbirds	Landbirds	
FACTOR	Rich	Comp	Rich	Rich	Rich & Abun	Comp
PROP	X	X	√√	X	√	√
MGZ3	√	√√	√√	X	X	√
YEAR	√	√	X	√√	√√	√√
HABITAT					√√√	√√√

Figure 21 Summary of main trends in bird species richness (Rich), abundance (Abun) and assemblage composition (Comp) by survey design factors

The absence of kites from the Warburton River in 2014 led us to speculate that riparian bird species richness might be adversely affected by high salinities in the Warburton River, i.e. that richness might fluctuate depending on whether water in the channels was drinkable (to wildlife) or not. A *t*-test, under the assumption of equal variances and ignoring the repeated-measures component, did not uphold this expectation – mean riparian landbird species richness at Warburton sites in 2014 under hypersaline conditions was 19.6, not significantly different from the mean of 20.9 in 2015 and 2016 under more favourable conditions (t_{15} = 0.57, P > 0.1). These averages would suggest that only the two kite species were absent from the riparian bird communities in 2014.

4.3 Key Drivers of Bird Diversity and Population Health

Hydrology is the ultimate driver of river and landscape health in these large dryland floodplain systems (e.g. Walker *et al.* 1995, 1997; Puckridge *et al.* 1998; Arthington & Balcombe 2011) and the variability of the annual hydrology plays an important role in maintaining ecosystem and biodiversity integrity (Puckridge *et al.* 2000; Bunn *et al.* 2006; Thoms 2006). The natural flow regime of the Diamantina-Warburton system holds the keys to the physical and ecological processes that maintain the habitats and the productivity that birds exploit in the region. Whether it be the prodigious productivity of Goyder Lagoon wetlands in big floods (Reid *et al.* 2009), the maintenance of riparian landforms and vegetation that support a rich riverine bird community, or the persistence of low flows in drought times that provide critical drought refuge for a wide variety of organisms, protecting and maintaining the natural flows and variability in the river is crucial.

In riparian environments two plant species in particular, Coolibah and Broughton Willow, proved to be of overriding importance in promoting high bird species richness, and the critical influence of the Coolibah extends to all parts of the floodplain in terms of its control of bird assemblage composition. In the ordination of 138 assemblages across riparian, floodplain and sand dune environments, the presence and abundance of coolibah explained over 65% of the variance in the placement of sites in three dimensions (see Table 22). The organising strength of Coolibah in this study matches that found along Cooper Creek by Reid & Gillen (2013). In these two great floodplain river systems in the Far North East of South Australia, Coolibah provides the structural framework on which patterns of bird community play out. In terms of predicting the number of landbird species at a riparian site, Broughton Willow was pre-eminent, with each additional unit of cover class accounting for an extra 3.7 landbird species (from REML model with fixed effects = YrF + Prop + Ac_Sali; Table 26). The habitat value of Broughton Willow was a novel finding of this study, and the species warrants closer study to see if the mechanisms by which its presence and abundance promote higher bird diversity can be elucidated. Two other diversity promoting features of riparian habitat in the study area linked to Broughton Willow were the predictor variables, number of small tree species (NSTsp), and the presence and abundance of mistletoe, particularly the Wire-leaf Mistletoe *Amyema preissii*. Broughton Willow was an important contributor to the effect of these variables by being the most common host of the Wire-leaf Mistletoe and by being the most abundant and widespread low tree species. It is possible there are intrinsic properties of Broughton Willow itself, e.g. being a legume and nitrogen-fixer, its foliage may be relatively nutritious and it may support high abundances of herbivorous insects of direct importance to insectivorous birds, or the production of sugary exudates from glands and through the sap-sucking insect pathway may be important. Less directly, it has been found throughout the world that the increased vertical habitat structure provided by shrubs and small trees in woodlands and forests is associated with higher avian species richness (MacArthur & MacArthur 1961; MacArthur *et al.* 1965; Recher 1969; Karr & Roth 1971; Willson 1974; Shurcliff 1980; Lambeck 1997), perhaps due to the greater variety of feeding opportunities (niches) presented.

Without having devised a 'habitat complexity score' (Lambeck 1997) fit for purpose for riparian environments in the study area, the results of the REML modelling clearly indicate that greater habitat complexity – greater cover of the dominant trees, greater abundance and diversity of small trees, medium-sized shrubs and low shrubs (vertical heterogeneity), less bare ground and more abiotic habitat attributes such as standing dead timber, hollows, fallen timber and litter – promotes greater landbird species richness, and land management should aim to promote these attributes.

In terms of maintaining their productivity, the great floodplain wetlands of Goyder Lagoon appear to manage themselves **provided the natural flooding and drying cycles are maintained**. Waterbirds flock into the region after any sustained flows through the system, and the size of the influx and breeding response apparently ratchet up with the greater the flood size and duration (Reid & Jaensch 2004; Reid *et al.* 2009). In 2001, in response to major floods in both the Diamantina River and Eyre-Georgina system, with extensive and prolonged inundation of most of Goyder Lagoon, Reid & Jaensch (2004) estimated 450,000 waterbirds on Goyder Lagoon from an aerial survey. On a smaller flood in 2009, Reid *et al.* (2009) derived estimates of 230,000 waterbirds in April and 300,000 in May 2009, from intensive aerial surveys of many transects. Evidence of breeding by numerous species was obtained across both these surveys, leading the authors to assert that the vast Lake Eyre Basin wetlands, of which Goyder Lagoon is a prime example, are a major engine room for the maintenance and recruitment of waterbird populations in Australia. Given the decline in abundance and breeding of waterbirds in the Murray-Darling Basin due to river regulations and overuse of water resources (Kingsford *et al.* 1999b, in press).

Fire management is a critical issue for the maintenance of waterbird breeding habitat in Goyder Lagoon, particularly for colonial nesting waterbirds, the group hit hardest by wetland degradation in the Murray-Darling Basin. Two plants especially, Lignum and River Cooba, but Coolibah also, are critical in providing nesting sites for this iconic group of birds, e.g. herons, egrets, ibis, spoonbills and cormorants. A major breeding site north of Pandiburra Bore, *ca* 7 km WSW Koonchera Waterhole, was severely damaged by a fire in the late 2000s. This area's recovery ought to be monitored and remediated if necessary. In the first instance, it should be investigated whether Lignum and River Cooba are regenerating naturally and to what extent. Regular aerial surveys are needed to assess how quickly and in what abundance colonial waterbirds return to this site to breed.

4.4 Ecosystem and Biogeographic Connectivity and Ecological Refugia

The network of rivers, their distributary channels, braids and floodouts, i.e. hydrological connectivity, promotes ecosystem and ecological connectivity in the study area. The sequential inundation of channels and wetlands which occurs during each flood event allows instream biota and waterbirds to capitalise on wetland resources over various spatial and temporal scales. Although regional flooding due to intense and heavy rainfall events in the catchment is the dominant organising force in these respects, local flooding and run-off from the stony plains in the region are also important, as we witnessed in 2015 with local freshening flows in the Warburton River and upper Kallakoopah Creek. Riverflow is the lifeblood to the region's riparian ecosystems, and their maintenance and health depend on natural streamflow in these rivers and the entire Georgina-Diamantina Catchment. Although Goyder Lagoon has a major disrupting influence on the connectivity of riparian woodlands and their distinctive bird assemblages across the entire study area, ecological connectivity remains high in this environment within the Diamantina management zone and within the Warburton-Kallakoopah management zone. Further survey work is required to document and understand the local range limits of various species with distributions in the region disrupted by Goyder Lagoon – Red-tailed Black-Cockatoo, Red-rumped Parrot, Bluebonnet, Thick-billed Grasswren, Southern Whiteface, Grey Shrike-thrush, Chirruping Wedgebill, White-browed Babbler and Chestnut-crowned Babbler. In some cases, the species have been recorded sparingly in zones from which they are largely absent, e.g. Bluebonnets at Andrewilla and Grey Shrike-thrush at Mona Downs in May 2016, and the ecological reasons that limit their distribution and spread merit investigation. Also, bird surveys at more sites along the Upper Warburton and Kallakoopah on Cowarie are warranted to explore the reasons for the decreased bird species richness in riparian habitats north of Stony Point Waterhole.

The deeper waterholes, particularly Andrewilla and Yammakira, are the crunch refugia in the region. Although this applies especially to instream aquatic biota (e.g. Sheldon *et al.* 2010), many birds are also dependent on these waterholes and the major channels and riparian vegetation generally. As argued by Morton *et al.* (2011), long-lived perennial plants store moisture, energy and nutrients, and can continue to grow and produce flowers, fruits and seeds through dry times. These pulses of resource provision are likely critical for a wide range of landbirds under drought conditions, as observed by Reid (2008) in the study area. Also the Goyder Lagoon complex is a highly significant, nationally recognised ecological refugium (Morton *et al.* 1995b: 99).

Under drought conditions even minor floods into the upper floodplains of Goyder Lagoon provide critical habitat for a range of birds, to which the observations around Burts Waterhole (May 2015), Tepamimi Waterhole and Koonchera Waterhole (this study and previous research: Reid & Jaensch 2004) attest. Although the limited flooding and greening up of the floodplain observed around Tepamimi Waterhole in 2014 and 2015 arose from an artesian bore, the response of birds was notable. Badman (1987) made similar observations in his study of birds on artificial bore drains in the wider region (see also Black *et al.* 1983). In the naturally inundated areas around Koonchera Waterhole and to the east of Burts Waterhole, bird diversity and abundance were much greater than in nearby unflooded parts of the floodplain (anecdotal observations). The Grey Grasswren, a flagship species of Goyder Lagoon (Black *et al.* 2009, 2012), may be critically dependent on these small regional flows during severe droughts for the population's persistence (Black *et al.* 2015), and as observations around Koonchera Waterhole have indicated (J. Reid, unpubl.). Other significant species that probably rely on these small areas of green vegetation on the floodplain during droughts include the Yellow Chat (Black *et al.* 1983) and Tawny Grassbird (Reid 2016); many other bird species (e.g. pigeons, quail, fairy-wrens, songlarks, Red-capped Robin, Australasian Pipit) capitalise on these patchy resources. This example illustrates the **nexus between hydrological connectivity and ecological refugia** (see also Selwood *et al.* (2017).

The north-south orientation of the river systems in the study area, and of the Georgina-Diamantina catchment generally, may facilitate migration of birds into, through and out of the region. Overseas some migrating bird species are known to follow physical (landform) features and areas of denser vegetation in poorly vegetated regions (Hutto 1985; Pennington *et al.* 2008; Newton 2010), but the study of migration routes, in terms of geographical detail, is in its infancy in the Australasian realm. However, during the current study apparent migratory movements of several species were observed, namely Spiny-cheeked Honeyeater, Pied Honeyeater, Masked and White-browed Woodswallow, and Black-faced Cuckoo-shrike, and there was a north-south component to the movements in most cases. Also, the unusual occurrence of Painted Honeyeater, Golden Whistler and Olive-backed Oriole, among others, is suggestive of autumnal northward migrations that these species undertake (e.g. Griffioen and Clarke 2002), and as suggested by Bond & Reid (2016) in the case of our oriole sighting in May 2015. As most Australian landbirds migrate in short hops during daylight hours, it makes sense that many of them would choose to follow the dense vegetation along the rivers rather than move through the open environments that characterise most of the far north of South Australia. Riparian vegetation affords better cover, shelter and feeding options, but rigorous research is required to explore these issues. Just as this region was once a great transport corridor for human goods in pre-European times (McBryde 1997, 2000), linking societies from the Gulf of Carpentaria to the Flinders Ranges and coasts of South Australia, so it may yet prove to be significant as a migration corridor for many landbird species, such as those already mentioned but also Rainbow Bee-eater, Sacred Kingfisher, Striated Pardalote, various honeyeater species, Rufous Whistler, Grey Fantail, Willie Wagtail, Magpie-lark and Tree Martin.

4.5 Management Issues

Experimental studies of cattle grazing management in the riparian zone are to be encouraged. Australian studies outside of the arid zone have demonstrated that over-grazing and degradation in riparian zones can have detrimental impacts on sensitive bird species (e.g. Skroblin & Legge 2012). More broadly, stock grazing has been shown to be associated with changes in the composition and abundance of bird communities and individual species along streams and rivers (e.g. Jansen & Robertson 2001a,b, 2005; Woinarski & Ash 2002; Martin *et al.* 2006; Martin & McIntyre 2007), and physical degradation of waterholes (Pettit *et al.* 2012; Leigh *et al.* 2013). It would be prudent to collaborate with pastoralists in a study of grazing management in selected parts of the riparian zones, to investigate whether access to the river frontage can be readily managed and to see if grazing protection of riparian vegetation and channel banks leads to physical and vegetation recovery and whether birds respond to these treatments.

The Endangered Plains-wanderer *Pedionomus torquatus* has been seen in recent years between Dulkaninna and the Clifton Hills Homestead, including along Mirra Mitta Creek (Sharon Oldfield, *personal communications*). An individual of the species was possibly seen (by J. Reid, **not** a definite sighting) on the outer edge of the floodplain, driving into Kalamunkinna Waterhole late one evening in May 2014), in habitat similar to where one was seen in winter 2000 on the outer floodplain near Ultoomurra Waterhole, again at night (J. Reid, unpubl. data). Habitat and particularly grazing management is the key to providing optimal conditions for the Plains-wanderer (Commonwealth of Australia 2016, *National Recovery Plan for the Plains-wanderer* Pedionomus torquatus). The species requires light to moderate grazing (**but neither heavy grazing nor no grazing**) to maintain the appropriate floristic and structural mix of the low, modest-density swards it inhabits. Lack of grazing can lead to sward cover becoming too heavy and the over-dominance of grasses (e.g. Baker-Gabb *et al.* 1990). Surveys are required (see below) and, depending on the outcomes and if critical areas of habitat are identified, negotiations with the pastoralists should be commenced about aligning localised habitat-management and cattle-production objectives.

Protection and sensitive management of colonial nesting waterbird breeding sites are needed and, in particular, continued vigour and regeneration of Lignum and River Cooba in those parts of Goyder Lagoon with longest inundation times needs monitoring (see above).

4.6 Particular Sites and Areas of Significance to Birds

The intermittently inundated wetlands of the Goyder Lagoon complex are of national and global heritage and conservation significance (Morton *et al.* 1995a,b), and are listed as a wetland of national importance under the *EPBC Act*, 2001 (as the Diamantina River Wetland System in the Directory of Important Wetlands, Department of Environment and Energy) and internationally recognised as an Important Bird Area (http://datazone.birdlife.org/site/factsheet/goyder-lagoon-iba-australia). Although knowledge of its bird fauna is still incomplete, as demonstrated by the discovery of Tawny Grassbird around Burts Waterhole (this study), Goyder Lagoon supports the largest-known population of the Diamantina subspecies of Grey Grasswren *Amytornis barbatus diamantina* (Black *et al.* 2010, 2011b), and is a breeding area for the Endangered Australian Painted Snipe *Rostratula australis* (Reid & Jaensch 2004). The area also supports significant populations of the nationally Vulnerable species Grey Falcon, and threatened South Australian species such as Flock Bronzewing, Eastern Grass Owl and Yellow Chat. The importance of Goyder Lagoon wetlands to recruitment in many populations of Australian waterbirds cannot be over-emphasised.

Although not occurring in riverine and floodplain habitats, the newly described pallid subspecies of Thick-Billed Grasswren *Amytornis modestus cowarie* (Black 2016; see also Black 2011; Black *et al.* 2011a; Austin *et al.* 2013) is restricted to the stony plains land system on Mungerannie and Cowarie stations within the study area, north to about Mt Gason. Black (2016) assessed its population under IUCN criteria, and has recommended that it be classified as Vulnerable due to its likely very small population size and limited extent of occurrence.

A similar, slightly larger area to that circumscribed for the Thick-billed Grasswren above, may prove to support a significant population of Plains-wanderer. Within the area north to the southernmost parts of Clifton Hills and west to the Warburton River, and focussing in the ecotonal habitats on the edge of the gibber plains and alluvial floodplains, targeted surveys of the

Plains-wanderer are required. Surveys of the species should be carried out in a range of seasons, since its occurrence in the region may be dependent on flooding and higher than usual rainfall events.

The entire riparian zone of the Diamantina River in South Australia, south to the 'DSplit' Waterhole, and beyond to include the highly significant deeper water refuges of Andrewilla and Yammakira, is a critical area of bird habitat, given the wide range of significant species that have been seen there with limited survey effort, e.g. Red-tailed Black-Cockatoo, Varied Lorikeet, Red-winged Parrot, Red-rumped Parrot, Spotted Bowerbird, Golden Whistler, White-browed Babbler and Olive-backed Oriole. A two-week survey of the zone is required to establish the population size and demographic structure of the cockatoo, and to find out how widespread are the bowerbird and babbler.

4.7 Significant Bird Species and their Research Needs

A moderate number of species classified by Gillam & Urban (2013) as Vulnerable (Letter-winged Kite, Peregrine Falcon, Australian Bustard, Brolga, Red-winged Parrot, Blue-winged Parrot) in the SAAL region occur regularly to sporadically in the study area, although the basis for the inclusion of Peregrine Falcon is unknown. Gillam & Urban (2013) also list 62 species as Rare in the SAAL region and which are shown (or are known) to occur in the study area. In the following list, **Endangered** or **Vulnerable**, without attribution, refers to the formal *EPBC Act*, *2001*, classification for Australia as a whole.

- <u>Magpie Goose</u>
  Endangered in SA (Gillam & Urban 2013); not seen this study; occasionally seen in Goyder Lagoon in big floods in low numbers; more aerial surveys of waterbirds in large floods needed.
- <u>Grey Falcon</u>
  Vulnerable nationally (Garnett *et al.* 2011); Rare in SA, Endangered in SAAL region (Gillam & Urban 2013); seen on Cowarie and reported from Cowarie and Kalamurina in 2014; previously seen at Koonchera and Yammakira (e.g. Reid & Gillen 1998; Reid 2008).
- <u>Curlew Sandpiper</u>
  Endangered. One bird seen near Tinnie Waterhole in April 2016. Additional ground and aerial surveys of shorebirds in the study area are needed.
- <u>Australian Painted Snipe</u>
  Endangered. Not seen this study; previously seen near Koonchera, and breeding there (Reid & Jaensch 2004). Additional ground and aerial surveys of shorebirds in the study area are needed.
- <u>Plains-wanderer</u>
  Endangered. Possibly seen this survey on northern parts of Cowarie; other reports from the study area; intensive surveys needed (see above).
- <u>Red-tailed Black-Cockatoo</u>
  Endangered in SA (Gillam & Urban 2013); flocks of 20 or more birds seen between Pandie Pandie Homestead and 'DSplit' Waterhole during field surveys; 35+ drinking at edge of Diamantina River near Pandie Pandie Homestead 9/5/17; also reported from Birdsville (Lynn Rowlands and Bully Booth, *personal communications*).
- <u>Spotted Bowerbird</u>
  Previously thought to be **Extinct** in SA (Boehm 1956; Parker & Reid 1979), until observation at 'DSplit' Waterhole May 2015. Two-weeks of intensive survey work needed along each of Diamantina River and Eyre Creek to determine the species' status.
- <u>Thick-billed Grasswren</u>
  Distinct subspecies (*Amytornis modestus cowarie*), locally endemic to study area (Black 2016: Vulnerable); not recorded this study; requires periodic monitoring and additional survey work to determine the taxon's precise distributional limits.

- Grey Grasswren
  Subspecies (*Amytornis barbatus diamantina*) has the core of its range centered on Goyder Lagoon; seen on all three visits to Koonchera and at Tepamimi Waterhole and near Kalamunkinna Waterhole in May 2015 during the study. Regular monitoring of the populations' distribution and abundance is required.

- Yellow Chat
  Endangered in SA (Gillam & Urban 2013); not seen this study; occasionally seen in Goyder Lagoon at Pandiburra Bore (Black *et al.* 1983) and elsewhere. Survey work needed.

- Painted Honeyeater
  Vulnerable. Endangered in SAAL region (Gillam & Urban 2013); seen at Stony Point and Yammakira waterholes in May 2015, perhaps in response to drought. Further surveys in autumns and spring needed, when the species is in passage between spring-summer breeding range in inland south-eastern Australia and winter range in the north-eastern interior.

4.8 Broader Research Needs

Surveys of waterbirds in Goyder Lagoon are needed, with a particular focus on breeding activity during large flood events. Opportunities to pursue integrated ground and aerial surveys should be explored.

Ground and aerial surveys of waterbirds on the large wetlands associated with the Kallakoopah Creek (salt lakes), Lake Howitt and other large wetlands in the study area should be undertaken after appropriate flooding and/or local rainfall events.

The riparian and floodplain environments of Eyre Creek and Kallakoopah Creek were under-studied due to logistical constraints. There is a dearth of knowledge about these systems. Survey work is urgently needed.

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Appendix 1 Density estimates of birds at each visit to subsites

Site: Andrewilla Waterhole

	2014	2015	2016	2014	2015	2016	2015	2016
English Name	**ANDRO**	**ANDRO**	**ANDRO**	**ANDRR**	**ANDRR**	**ANDRR**	**ANDRS**	**ANDRS**
White-plumed Honeyeater	1	1.2	0.8	2.8	2	7	0.4	1
Fairy Martin	0	0	1.6	0.4	0	4	0	1
Tree Martin	0	0	0.8	0.8	1.4	1.6	0	0.6
Zebra Finch	2.4	0	0	0.4	0	0	0.8	0
White-browed Babbler	0.1	0	0	0.6	1.6	0.6	0	0
Diamond Dove	0.1	2	0	0	0	0	0.1	0.6
Galah	0.1	0	0.1	0.8	0	0.8	0	0.8
Willie Wagtail	0.4	0.2	0.6	0.4	0.4	0.4	0	0.2
Crested Pigeon	0.2	0.4	0.4	0.6	0	0	0.1	0.8
Peaceful Dove	0.4	0	0.2	0.4	0.6	0.4	0.2	0
Budgerigar	0	0	0	0	0	1.6	0.4	0
Grey Shrike-thrush	0.1	0	0	0.6	0.4	0.8	0	0
Variegated Fairy-wren	0	0	0	0	0	0	0	1.8
White-backed Swallow	0.1	0.2	0	0.4	0.2	0.4	0	0
Magpie-lark	0	0	0.1	0.1	0.4	0.4	0	0.2
Black-faced Woodswallow	0	0	0.8	0	0	0	0	0.2
Australian Raven	0	0	0	0	0.6	0.2	0	0.2
Whistling Kite	0	0	0	0.2	0.2	0.4	0	0
Little Corella	0	0	0	0.4	0	0	0	0.4
Red-rumped Parrot	0	0	0	0.2	0.2	0	0	0.4
White-breasted Woodswallow	0	0	0	0.4	0	0.4	0	0
Black Kite	0	0	0.4	0	0.2	0	0	0
Red-capped Robin	0	0	0	0	0	0	0	0.4
Yellow-throated Miner	0	0	0	0.4	0	0	0	0
Red-backed Kingfisher	0	0	0	0	0	0.1	0	0.2
Blue Bonnet	0.2	0	0	0	0	0	0	0
Rufous Whistler	0	0	0	0	0	0	0	0.2
Mistletoebird	0	0	0	0.2	0	0	0	0
Red-browed Pardalote	0	0	0	0.2	0	0	0	0
Striated Pardalote	0	0	0	0.2	0	0	0	0
Sacred Kingfisher	0	0	0	0	0	0.1	0	0
Abun	**5.1**	**4.0**	**5.8**	**10.5**	**8.2**	**19.2**	**2.0**	**9.0**
Rich	**11**	**5**	**10**	**20**	**12**	**16**	**6**	**16**

Andrewilla Waterhole (cont.) – Additional species

English Name	ANDR14	ANDR15		ANDR16
Australian Pelican	1	1		1
White-necked Heron	1	1		1
White-faced Heron	1	1		1
Black-faced Cuckoo-shrike	1	1		1
Australian Magpie	1	1		1
Australian Wood Duck	0	1		1
Australian Owlet-nightjar	1	0		1
Pied Cormorant	0	1		1
Spotted Harrier	1	0		1
Black-fronted Dotterel	0	1		1
Caspian Tern	1	0		1
Horsfield's Bronze-Cuckoo	0	1		1
Southern Boobook	1	0		1
Spiny-cheeked Honeyeater	0	1		1
Little Crow	1	0		1
Plumed Whistling-Duck	0	0		1
Pink-eared Duck	0	0		1
Grey Teal	0	0		1
Hardhead	0	0		1
Flock Bronzewing	0	0		1
Spotted Nightjar	0	0		1
Australasian Darter	0	0		1
Great Cormorant	0	0		1
Nankeen Night-Heron	0	1		0
Straw-necked Ibis	0	0		1
Royal Spoonbill	0	0		1
Collared Sparrowhawk	1	0		0
Nankeen Kestrel	0	0		1
Australian Hobby	0	0		1
Black Falcon	0	1		0
Brolga	0	0		1
Banded Lapwing	0	0		1
Gull-billed Tern	0	0		1
Cockatiel	0	0		1
Black-eared Cuckoo	0	0		1
Pallid Cuckoo	0	0		1
Eastern Barn Owl	0	0		1

English Name	ANDR14	ANDR15		ANDR16
Pied Honeyeater	0	0		1
Crimson Chat	0	0		1
White-winged Triller	0	0		1
Masked Woodswallow	0	0		1
White-browed Woodswallow	0	0		1
Rufous Songlark	0	0		1
Australasian Pipit	0	0		1

Site: Burts Waterhole

	2015	2015	2015	2015
English Name	**BURTD**	**BURTO**	**BURTP**	**BURTR**
Stubble Quail	0	0	0.2	0
Crested Pigeon	0.4	0	0	0.8
Black Kite	0	0	0.2	0
Nankeen Kestrel	0.2	0.1	0	0
Horsfield's Bronze-Cuckoo	0	0	0	0.2
White-winged Fairy-wren	0.1	0	0.6	0
Variegated Fairy-wren	0.6	1	1.8	0.1
Singing Honeyeater	0	0.2	0	0
White-plumed Honeyeater	0.4	0.4	0.2	5.2
Spiny-cheeked Honeyeater	0	0	0	0.4
Grey Shrike-thrush	0	0	0	0.2
Willie Wagtail	0.2	0.6	0	0.4
Australian Raven	0	0	0	0.2
Magpie-lark	0	0	0	0.6
Red-capped Robin	0	0.6	0.2	0
Tawny Grassbird	0	0.2	0	0
Brown Songlark	0	0	0.1	0
Fairy Martin	0	0.2	0	1
Tree Martin	0	0.4	0	18.8
Mistletoebird	0	0	0	0.8
Zebra Finch	0	2.2	0	0.8
Abun	1.9	5.9	3.3	29.5
Rich	6	10	7	13

Burts Waterhole (cont.) – Additional species

English Name	BURT15
Diamond Dove	1
Australian Pelican	1
White-necked Heron	1
White-faced Heron	1
Whistling Kite	1
Spotted Harrier	1
Swamp Harrier	1
Black Falcon	1
Brolga	1
Australian Spotted Crake	1
Black-fronted Dotterel	1
Galah	1
Little Corella	1
Cockatiel	1
Red-rumped Parrot	1
Budgerigar	1
Red-backed Kingfisher	1
Yellow-throated Miner	1
Crimson Chat	1
Black-faced Cuckoo-shrike	1
Rufous Whistler	1
White-breasted Woodswallow	1
Masked Woodswallow	1
Black-faced Woodswallow	1
Restless Flycatcher	1
White-backed Swallow	1
Australasian Pipit	1

Site: Cowarie Crossing

	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
English Name	**COWCD**	**COWCD**	**COWCF**	**COWCF**	**COWCF**	**COWCO**	**COWCO**	**COWCO**	**COWCR**	**COWCR**	**COWCR**
Common Bronzewing	0	0	0	0	0	0	0	0	0	0.1	0
Crested Pigeon	0	0	0	0	0	0.4	0.4	0.6	1	0	0.2
Diamond Dove	0	0.6	0	1	2.2	0	0	1	0.4	0	1.2
Peaceful Dove	0	0	0	0	0	0	0	0	0	0	0.2
Whistling Kite	0	0	0	0	0	0	0	0	0	0.8	0.4
Black Kite	0	0	0	0	0.2	0	0	0	0	0	0.4
Galah	0	0	0.4	0.4	0	0.4	1.8	1.6	1.8	2.4	0.2
Blue Bonnet	0	0.1	0.4	0.1	0.1	0.8	0.4	0.8	0.4	0.4	0.4
Budgerigar	0	0.1	0	0	0.4	0	0.8	0	0	0	1
Horsfield's Bronze-Cuckoo	0	0.4	0.1	0	0	0	0	0	0.1	0	0
Red-backed Kingfisher	0	0	0	0	0	0	0	0.1	0	0.1	0.1
White-winged Fairy-wren	1.8	2.4	0.6	0	0.8	0	0	0.1	0	0	0
Variegated Fairy-wren	0	1.4	0.8	1	0.6	0.6	0	0.8	1.6	1.4	0.8
Eyrean Grasswren	0	0.4	0	0	0	0	0	0	0	0	0
Red-browed Pardalote	0.1	0.2	0	0	0	0	0	0.2	0	0.2	0
Striated Pardalote	0	0	0	0	0	0.2	0	0	0.1	0.4	0
White-plumed Honeyeater	0	0.4	0.1	0.6	2.4	1.6	4.6	5	1.4	3.6	6.6
Yellow-throated Miner	0	0	0	0	0	0	0	0.4	0.2	0.2	2
Spiny-cheeked Honeyeater	0	0	0	0	0	0.2	0	0	0.6	0	0.4
Crimson Chat	0	0	0	0	0	0	0	0.2	0	0	0
Chestnut-crowned Babbler	0	0	0	0	0.1	0.1	0	0.1	0.1	0	0
Chirruping Wedgebill	0	0	0.1	0.2	0.4	0.4	0	0.2	0.4	0.2	0.4

	2015	2016	2014	2015	2016	2014	2015	2016	2014	2015	2016
English Name	**COWCD**	**COWCD**	**COWCF**	**COWCF**	**COWCF**	**COWCO**	**COWCO**	**COWCO**	**COWCR**	**COWCR**	**COWCR**
Black-faced Cuckoo-shrike	0	0	0	0	0	0	0	0	0	0	0.4
Rufous Whistler	0	0	0	0	0	0	0	0	0.2	0	0
White-breasted Woodswallow	0	0	0.2	0	0	0.2	0	0	0.8	0	0
Masked Woodswallow	0	0	0	0	0.4	0	2.2	4.8	0	0.4	2
White-browed Woodswallow	0	0	0	0	0	0	1.2	0.4	0	0	0.8
Black-faced Woodswallow	0	0.2	0.1	0	0.4	0.1	0.6	0.1	0.4	0	0.4
Australian Magpie	0	0	0	0	0	0	0	0	0.4	0	0
Willie Wagtail	0	0.6	0.2	0.2	0.2	0.2	0.4	0.2	1.2	0.4	0.4
Australian Raven	0	0	0	0	0	0.1	0	0	0.1	0.1	0.2
Magpie-lark	0	0	0	0	0	0	0	0	0.4	0.1	0.4
Red-capped Robin	0	0	0	0.4	0	0	0	0	0	0	0
White-backed Swallow	0	0.4	0.1	0.4	0.4	0	0.4	0	0.4	0.4	0.4
Fairy Martin	0	0	0.2	0	0	0	0	0	0	0	0
Tree Martin	0	0	0	0	1.2	0	1	0.8	0.8	1.6	0.4
Mistletoebird	0	0	0	0	0	0.4	0	0	0.4	0.2	0.1
Zebra Finch	3	18	0	0.4	1.8	0	0.4	2	0	0	2.8
Abun	**4.9**	**25.2**	**3.3**	**4.7**	**11.6**	**5.7**	**14.2**	**19.4**	**13.2**	**13.0**	**22.6**
Rich	**3**	**13**	**12**	**10**	**15**	**14**	**12**	**19**	**22**	**18**	**25**

Cowarie Crossing (cont.) – Additional species

English Name	CROS14	CROS15	CROS16
Pink-eared Duck	0	1	1
Grey Teal	0	1	1
Hoary-headed Grebe	0	1	0
Tawny Frogmouth	0	1	0
Australian Owlet-nightjar	0	1	1
Great Cormorant	0	1	1
Little Black Cormorant	0	1	1
Pied Cormorant	0	1	0
Australian Pelican	0	0	1
White-necked Heron	0	1	1
White-faced Heron	0	1	1
Straw-necked Ibis	0	0	1
Yellow-billed Spoonbill	0	0	1
Black-shouldered Kite	0	0	1
Little Eagle	0	0	1
Brown Falcon	0	1	0
Australian Hobby	0	1	0
Eurasian Coot	0	1	0
Black-winged Stilt	0	0	1
Red-necked Avocet	0	0	1
Black-fronted Dotterel	1	1	1
Little Button-quail	0	1	1
Gull-billed Tern	0	0	1
Little Corella	0	1	1
Cockatiel	0	0	1
Black-eared Cuckoo	0	1	0
Pallid Cuckoo	0	1	0
Eastern Barn Owl	0	0	1
Grey Fantail	1	0	0
Little Crow	0	0	1
Rufous Songlark	0	0	1

Site: Double Bluff Yard

English Name	DBYDD	DBYDD	DBYDO	DBYDO	DBYDP	DBYDP	DBYDR	DBYDR	DBYDS
Crested Pigeon	0	0.4	0.1	0	0.2	0.2	1.6	1.6	0.8
Diamond Dove	0	0.2	0	1	0.8	0	0	14.8	0
Peaceful Dove	0	0	0	0	0	0	0.6	1.2	0.8
Whistling Kite	0	0	0	0	0	0	0	0.2	0.4
Black Kite	0	0	0	0	0	0	0	0.2	0
Little Eagle	0	0	0	0	0	0	0	0	0.2
Nankeen Kestrel	0	0	0	0	0	0.1	0	0	0
Red-tailed Black-Cockatoo	0	0	0	0	0	0	0.1	0	0
Galah	0	0	0	0.1	0	0	0.1	0.8	1.6
Little Corella	0	0	0	0	0	0	0.1	0	0.4
Cockatiel	0	0	0	0	0	0	0	0.1	0
Red-rumped Parrot	0	0	0	0	0.4	0	0	0.4	0
Budgerigar	0	0	0	0	0	3.4	0	6.4	1.2
Horsfield's Bronze-Cuckoo	0	0	0	0	0	0	0.1	0.2	0
White-winged Fairy-wren	1	0.6	1	0	0	0	0	0	0
Variegated Fairy-wren	0	0	0.6	0	0.6	0	0.1	0.6	0
Striated Pardalote	0	0	0.2	0	0	0	0	0	0
White-plumed Honeyeater	0	0	1.2	0.6	0.6	0.8	3.2	3.4	4.2
Yellow-throated Miner	0	0	0	0	0	0	0.1	0	0
Spiny-cheeked Honeyeater	0	0	0	0	0.1	0	0.2	0	0.4
Black-faced Cuckoo-shrike	0	0	0	0	0	0	0.1	0.2	0
Rufous Whistler	0	0	0	0	0.2	0	0.4	0	0
Grey Shrike-thrush	0	0	0	0	0.2	0	1.4	0.4	1

English Name	DBYDD	DBYDD	DBYDO	DBYDO	DBYDP	DBYDP	DBYDR	DBYDR	DBYDS
White-breasted Woodswallow	0	0	0	0	0	0	0	0.2	0
Masked Woodswallow	0	0	0	0	0	0	0	0.4	0
Black-faced Woodswallow	0.4	0	0	0	0	0	0	0	0
Willie Wagtail	0	0	0	0.4	0	0.6	0.6	5	0.8
Australian Raven	0	0.2	0	0	0.2	0	0.4	0.1	0
Magpie-lark	0	0	0	0	0	0	0.1	1	0.1
Red-capped Robin	0.4	1	0.8	1.2	0.4	0.2	0	0	0
White-backed Swallow	0.4	0.2	0.1	0.4	0.4	0	0.4	0.6	0
Fairy Martin	0	0	0	0	0	0	0	0.8	0
Tree Martin	0	0	0.4	0.6	0.2	0	0	1.2	0.8
Mistletoebird	0	0	0	0	0.2	0	1	0.4	1.6
Zebra Finch	0	0.1	0	0.4	0.4	4.8	1	1.6	1.6
Abun	**2.2**	**2.7**	**4.4**	**4.7**	**4.9**	**10.1**	**11.6**	**41.8**	**15.9**
Rich	**4**	**7**	**8**	**8**	**14**	**7**	**19**	**24**	**15**

Double Bluff Yard (cont.) – Additional species

English Name	DBYD15	DBYD16
Grey Teal	1	1
Pacific Black Duck	0	1
Hoary-headed Grebe	1	0
Common Bronzewing	1	0
Australian Owlet-nightjar	1	1
Australian Pelican	1	0
White-necked Heron	1	1
White-faced Heron	0	1
Royal Spoonbill	0	1
Wedge-tailed Eagle	1	0
Black-fronted Dotterel	1	1
Southern Boobook	1	0
Eastern Barn Owl	1	0
Red-backed Kingfisher	1	1
Red-browed Pardalote	0	1
Crimson Chat	1	1
White-winged Triller	1	1
Olive-backed Oriole	1	0
Australian Magpie	1	1
Little Crow	1	0

Site: Diamantina Split

	2014	2015	2014	2015	2016	2014	2015	2016	2014	2015	2016
English Name	**DSPLD**	**DSPLD**	**DSPLO**	**DSPLO**	**DSPLO**	**DSPLR**	**DSPLR**	**DSPLR**	**DSPLS**	**DSPLS**	**DSPLS**
Brown Quail	0	0	0	0	0	0	0	0	0	0.4	0
Common Bronzewing	0	0	0	0	0	0	0	0	0	0.2	0.2
Crested Pigeon	0	0.2	0.1	0.4	0.4	2	0.4	0	0.8	1	0.4
Diamond Dove	0	0	0	0	0.2	0.1	0.6	0.2	0	0	0
Peaceful Dove	0	0	0	0.2	0	0.1	0.6	0.6	0.8	0	0.1
Whistling Kite	0	0	0	0	0.2	0	0	0.2	0.2	0.2	0.2
Black Kite	0	0	0	0	0	0	0	0	0	0	0.1
Galah	0	0	1.8	0.4	0.8	0.4	1.2	0.2	0	0	0.8
Little Corella	0	0	0	0	0.1	0	0	0.1	0	0	0
Red-rumped Parrot	0	0	0	0.1	0	0.6	0.8	0	0	0.4	0
Budgerigar	0	0	0	0	0.1	0	0	0.4	0	0	0
Horsfield's Bronze-Cuckoo	0	0	0	0.2	0	0	0	0	0	0.2	0
Black-eared Cuckoo	0	0	0	0	0	0	0	0.2	0	0	0.1
Red-backed Kingfisher	0	0	0	0.2	0.2	0.2	0	0	0	0	0.2
Sacred Kingfisher	0	0	0	0	0	0	0	0.2	0	0.2	0
Spotted Bowerbird	0	0	0	0	0	0	0	0	0	0.2	0
White-winged Fairy-wren	2.2	0.6	0	0	0	0	0	0	0	0	0
Variegated Fairy-wren	0.6	0	0	0	0	0	0.1	0.6	2.2	2	1.4
Red-browed Pardalote	0	0	0	0	0	0	0	0	0.2	0	0.1
White-plumed Honeyeater	0	0.1	0.8	1.4	2	3.6	3.8	4	5.2	6.2	6.2
Yellow-throated Miner	0	0	0	0	0	0	0.1	0	0.4	0	0.1
Spiny-cheeked Honeyeater	0	0	0	0	0	1	0.2	0.4	2.2	3.6	1

	2014	2015	2014	2015	2016	2014	2015	2016	2014	2015	2016
English Name	**DSPLD**	**DSPLD**	**DSPLO**	**DSPLO**	**DSPLO**	**DSPLR**	**DSPLR**	**DSPLR**	**DSPLS**	**DSPLS**	**DSPLS**
White-browed Babbler	0	0	0	0	0	0.2	0	0	0	0	0
Black-faced Cuckoo-shrike	0	0	0	0	1	0.1	0.1	0	0.2	0	0.1
Golden Whistler	0	0	0	0	0	0	0	0	0	0.2	0
Rufous Whistler	0	0	0.2	0.2	0.2	0	0	0	0	0.4	0.2
Grey Shrike-thrush	0	0	0	0.8	0.1	0.8	1.4	0.4	0.8	1.2	0.8
White-breasted Woodswallow	0	0	0	0	0	0.6	0.8	0	0.2	0	0
Black-faced Woodswallow	0.6	0	0.8	0	0.4	0	0	0	0	0	0
Grey Fantail	0	0	0	0	0	0	0	0	0	0	0.2
Willie Wagtail	0.2	0	0.2	0.2	1	0.4	1	0.8	0.6	1	2.4
Australian Raven	0	0	0	0	0	0.4	0.1	0	0.4	0.1	0
Magpie-lark	0	0	0	0	0.1	0.1	0.1	0.1	0.6	0	0
White-backed Swallow	0.4	0.8	0	0.1	0	0.4	0.4	0	0.6	0.4	0.8
Fairy Martin	0	0	0	0	0	0.4	0.4	3.8	0.8	0.2	1
Tree Martin	0	0	0	0	0	0.4	1.2	0.8	0.2	0.8	0
Mistletoebird	0	0	0	0	0	0.4	0.8	0.4	1	1.6	3
Zebra Finch	0	0.4	0.4	0	0.4	1.2	1.4	0	0.1	0.4	1.2
Abun	**4.0**	**2.1**	**4.3**	**4.2**	**7.2**	**13.4**	**15.5**	**13.4**	**17.5**	**20.9**	**20.6**
Rich	**5**	**5**	**7**	**11**	**15**	**20**	**20**	**17**	**19**	**21**	**22**

Diamantina Split (cont.) – Additional species

English Name	DSPL14	DSPL15	DSPL16
Australian Wood Duck	0	1	0
Hoary-headed Grebe	0	1	0
Spotted Nightjar	0	0	1
Australian Owlet-nightjar	1	1	1
Little Black Cormorant	1	0	0
Pied Cormorant	1	0	0
Australian Pelican	1	1	0
White-necked Heron	1	1	0
White-faced Heron	0	1	0
Royal Spoonbill	0	0	1
Yellow-billed Spoonbill	0	0	1
Wedge-tailed Eagle	0	1	0
Black-fronted Dotterel	1	1	1
Masked Lapwing	1	0	0
Red-tailed Black-Cockatoo	0	1	0
Cockatiel	0	0	1
Southern Boobook	0	0	1
Masked Woodswallow	0	0	1
Australian Magpie	0	1	1
Little Crow	1	0	1

Site: Goyder Lagoon Waterhole

	2014	2015	2015	2014	2015	2015
English Name	**GOYDO**	**GOYDO**	**GOYDP**	**GOYDR**	**GOYDR**	**GOYDS**
Crested Pigeon	0	0	0	0.8	0.1	0
Diamond Dove	0	0	0	0	0.2	0.2
Peaceful Dove	0	0	0	0	0.2	0.4
Whistling Kite	0	0	0	0	0	0.4
Galah	0	0	0	0.4	0	0
Little Corella	0	0	0	0	0	0.1
Variegated Fairy-wren	0	0	0.8	0.4	0	0
White-plumed Honeyeater	0	0.1	0	2.8	2.8	2.4
Spiny-cheeked Honeyeater	0	0	0	0	0	0.4
White-breasted Woodswallow	0	0	0.1	0	0	0.4
Willie Wagtail	0.2	0.1	0.1	1	0.8	0
Australian Raven	0	0	0	0.2	0.1	0.2

	2014	2015	2015	2014	2015	2015
English Name	**GOYDO**	**GOYDO**	**GOYDP**	**GOYDR**	**GOYDR**	**GOYDS**
Magpie-lark	0	0	0	0.4	0.2	0
Brown Songlark	0	0	0.2	0	0	0
White-backed Swallow	0	0	0	0.2	0	0
Welcome Swallow	0	0	0	0	0.2	0
Fairy Martin	0	0.1	0	0	0	1
Tree Martin	0	0	0.2	0	0.6	3
Zebra Finch	0	0	0.6	0	0	0
Australasian Pipit	0.2	0	0	0	0	0
Abun	**0.4**	**0.3**	**2.0**	**6.2**	**5.2**	**8.5**
Rich	**2**	**3**	**6**	**8**	**9**	**10**

Goyder Lagoon Waterhole (cont.) – Additional species

English Name	**GOYD14**	**GOYD15**
Plumed Whistling-Duck	0	1
Musk Duck	0	1
Australian Wood Duck	1	1
Pink-eared Duck	1	1
Australasian Shoveler	1	0
Grey Teal	1	1
Pacific Black Duck	1	1
Hardhead	1	0
Hoary-headed Grebe	1	1
Great Cormorant	0	1
Little Black Cormorant	0	1
Pied Cormorant	0	1
Australian Pelican	0	1
White-necked Heron	1	1
White-faced Heron	1	1
Royal Spoonbill	0	1
Yellow-billed Spoonbill	1	1
Nankeen Kestrel	0	1
Eurasian Coot	1	0
Black-winged Stilt	1	0
Red-necked Avocet	1	1
Banded Stilt	1	0
Red-capped Plover	1	0

English Name	GOYD14	GOYD15
Black-fronted Dotterel	1	1
Masked Lapwing	0	1
Common Greenshank	1	0
Caspian Tern	1	0
Whiskered Tern	0	1
Silver Gull	0	1
Cockatiel	0	1
Budgerigar	0	1
Red-backed Kingfisher	0	1
Striated Pardalote	1	0
Yellow-throated Miner	1	0
Black-faced Cuckoo-shrike	0	1
Black-faced Woodswallow	1	1
Australian Magpie	1	0
Little Crow	1	1
Little Grassbird	1	0
Mistletoebird	0	1

Site: Kalamunkinna Waterhole

	2014	2015	2014	2015	2014	2015
English Name	**KALAO**	**KALAO**	**KALAR**	**KALAR**	**KALAS**	**KALAS**
Common Bronzewing	0	0	0.1	0	0.4	0
Crested Pigeon	0.2	0	0.1	0	0.6	0
Diamond Dove	0	0	0.4	1.2	0	0.4
Galah	0	0.4	1.2	0.8	0.4	0.2
Red-rumped Parrot	0	0	0	0	0.1	0
Horsfield's Bronze-Cuckoo	0	0	0.1	0	0	0
Red-backed Kingfisher	0	0.1	0	0	0	0
White-winged Fairy-wren	0.8	1.2	0	0	0	0
Variegated Fairy-wren	0.4	0.8	0.8	1.8	0	0
White-plumed Honeyeater	0	0.4	2	4.8	2.8	4.8
Yellow-throated Miner	0	0.2	0	0	0	0
Spiny-cheeked Honeyeater	0	0	0.2	0.4	0.4	0
Chestnut-crowned Babbler	0	0	0	0.1	0	0
Chirruping Wedgebill	0	0	0.1	0.2	0	0
White-breasted Woodswallow	0.2	0	0	0.4	0	0
Black-faced Woodswallow	0	0	0.1	0	0.8	0

	2014	2015	2014	2015	2014	2015
English Name	**KALAO**	**KALAO**	**KALAR**	**KALAR**	**KALAS**	**KALAS**
Australian Magpie	0	0	0	0.1	0	0
Willie Wagtail	0.1	0	0.1	0.6	0.4	0
Australian Raven	0	0	0.1	0	0	0.4
Magpie-lark	0	0	0	0.4	0	0
White-backed Swallow	0	0	0.2	0.4	0.2	0
Tree Martin	0	0	0.4	0	0	0
Mistletoebird	0	0	0.4	0.2	0.2	0.2
Abun	**1.7**	**3.1**	**6.3**	**11.4**	**6.3**	**6.0**
Rich	**5**	**6**	**15**	**13**	**10**	**5**

Kalamunkinna Waterhole (cont.) – Additional species

English Name	KALA14	KALA15
Peaceful Dove	1	0
Spotted Nightjar	0	1
Australian Owlet-nightjar	1	1
Great Cormorant	0	1
White-necked Heron	0	1
White-faced Heron	1	1
Whistling Kite	0	1
Black Kite	0	1
Black-fronted Dotterel	1	0
Little Corella	0	1
Cockatiel	0	1
Blue Bonnet	1	1
Budgerigar	1	1
Grey Grasswren	1	0
Striated Pardalote	1	0
Crimson Chat	0	1
Black-faced Cuckoo-shrike	0	1
Masked Woodswallow	0	1
White-browed Woodswallow	0	1
Little Crow	1	0
Fairy Martin	1	0
Zebra Finch	1	1

Site: Koonchera Waterhole

	2014	2015	2016	2014	2015	2014	2015
English Name	**KOOND**	**KOOND**	**KOOND**	**KOONO**	**KOONO**	**KOONR**	**KOONR**
Crested Pigeon	0.2	2	0	0	0	0.4	0.4
Diamond Dove	0	0	0	0	0	0	0.6
Whistling Kite	0	0	0	0	0	0.4	0.2
Black Kite	0	0	0.4	0	0	0	0.6
Swamp Harrier	0	0	0.2	0	0	0	0
Nankeen Kestrel	0	0.4	0	0	0	0	0
Australian Hobby	0	0	0	0	0	0.2	0
Little Corella	0	1.4	0.4	0	0	0.1	4.6
Horsfield's Bronze-Cuckoo	0	0	0.6	0	0	0	0
White-winged Fairy-wren	0.8	0.6	0	0	0.4	0	0.6
Variegated Fairy-wren	0	1	0	0	0.1	0	0
Grey Grasswren	0	0	0	0.6	0.6	0	0
Eyrean Grasswren	0	0	0.2	0	0	0	0
Singing Honeyeater	0.4	0.6	0.2	0	0.1	0	0
White-plumed Honeyeater	0.4	0.2	0	0.2	0	2.2	2.2
Spiny-cheeked Honeyeater	0	0	0	0	0	0.2	0.2
Orange Chat	0.1	0	0	0	0	0	0
Black-faced Cuckoo-shrike	0	0	0	0	0	0	0.1
White-winged Triller	0	0	0.2	0	0	0	0
Rufous Whistler	0	0.2	0	0	0	0	0.2
White-breasted Woodswallow	0	0	0	0	0	0.4	0.2
Australian Magpie	0	0	0	0	0.1	0	0
Grey Fantail	0	0	0	0	0	0.1	0
Willie Wagtail	0.4	0.6	0.8	0.2	0	1.2	0.8
Australian Raven	0	0.4	0	0	0	0	0.2
Little Crow	0	0.6	0	0	0	0	0
Magpie-lark	0	0	0	0	0	0.2	0.2
Red-capped Robin	0	0.1	0	0	0	0	0
Little Grassbird	0	0	0	0.1	0	0	0
White-backed Swallow	0	0	0.2	0	0	0	0
Fairy Martin	0.8	0.2	0.8	0	0	1.2	0.4
Tree Martin	0.4	0	1.2	0	0	3.2	3.6
Mistletoebird	0	0	0	0	0	0	0.8
Zebra Finch	0.4	0.6	0.2	0.1	0.1	1.8	1.4
Australasian Pipit	0	0	0	0.1	0	0	0
Abun	**3.9**	**8.9**	**5.4**	**1.3**	**1.4**	**11.6**	**17.3**
Rich	**9**	**14**	**12**	**6**	**6**	**13**	**18**

Koonchera Waterhole (cont.) – Additional species

English Name	**KOON14**	**KOON15**	**KOON16**
Emu	0	1	1
Plumed Whistling-Duck	1	1	1
Musk Duck	1	1	0
Freckled Duck	1	0	0
Black Swan	0	0	1
Australian Wood Duck	1	1	1
Pink-eared Duck	1	1	1
Australasian Shoveler	1	1	1
Grey Teal	1	1	1
Pacific Black Duck	1	1	1
Hardhead	1	1	1
Australasian Grebe	1	0	0
Hoary-headed Grebe	1	1	1
Great Crested Grebe	0	0	1
Flock Bronzewing	1	0	0
Australasian Darter	1	0	1
Little Pied Cormorant	1	0	0
Little Black Cormorant	1	0	1
Pied Cormorant	1	0	1
Australian Pelican	0	1	0
White-necked Heron	1	1	1
Eastern Great Egret	1	0	1
White-faced Heron	1	1	1
Glossy Ibis	0	0	1
Australian White Ibis	0	1	0
Straw-necked Ibis	0	0	1
Royal Spoonbill	0	1	1
Yellow-billed Spoonbill	1	1	1
Brown Goshawk	0	0	1
Collared Sparrowhawk	1	0	1
Spotted Harrier	1	0	0
Wedge-tailed Eagle	1	1	0
Little Eagle	0	1	0
Brown Falcon	1	1	1
Brolga	1	1	1
Purple Swamphen	0	0	1
Dusky Moorhen	0	1	0

English Name	KOON14	KOON15	KOON16
Eurasian Coot	1	1	0
Black-winged Stilt	1	1	1
Red-necked Avocet	0	1	0
Red-capped Plover	0	0	1
Black-fronted Dotterel	1	1	1
Red-kneed Dotterel	0	0	1
Banded Lapwing	1	0	0
Masked Lapwing	1	0	1
Australian Pratincole	0	0	1
Gull-billed Tern	0	0	1
Caspian Tern	1	0	0
Whiskered Tern	0	0	1
Silver Gull	1	1	0
Galah	0	1	0
Budgerigar	1	1	1
Blue-winged Parrot	0	1	0
Southern Boobook	0	1	0
Red-backed Kingfisher	1	1	0
Striated Pardalote	1	0	0
Pied Honeyeater	0	0	1
Yellow-throated Miner	1	0	0
Crimson Chat	0	0	1
Cinnamon Quail-thrush	0	0	1
Chirruping Wedgebill	0	1	0
Grey Shrike-thrush	0	1	0
Masked Woodswallow	0	0	1
Australian Reed-Warbler	0	0	1
Welcome Swallow	1	0	0

Site: Kuncherinna Waterhole

English Name	KUNCD	KUNCO	KUNCR
Crested Pigeon	0	0.2	0.4
Diamond Dove	0	0	0.2
Galah	0	1.4	0.4
Blue Bonnet	0	0.2	0.1
White-winged Fairy-wren	1.2	0	0
Variegated Fairy-wren	0	0	1.2

English Name	KUNCD	KUNCO	KUNCR
Red-browed Pardalote	0	0	0.2
White-plumed Honeyeater	0.2	0.6	4.6
Crimson Chat	0	0	0.2
Chestnut-crowned Babbler	0	0.8	0
Chirruping Wedgebill	0	0	0.1
Black-faced Woodswallow	1.2	0	0.1
Willie Wagtail	0	0.2	0.4
Little Crow	0	0	0.1
White-backed Swallow	0.6	0.1	0.4
Fairy Martin	0	0.1	0.4
Tree Martin	0	0.4	0
Abun	**3.2**	**4.0**	**8.8**
Rich	**4**	**9**	**14**

Kuncherinna Waterhole (cont.) – Additional species

English Name	KUNC14
Black-fronted Dotterel	1
Caspian Tern	1
Little Corella	1
Budgerigar	1
Horsfield's Bronze-Cuckoo	1
Striated Pardalote	1
Orange Chat	1
White-breasted Woodswallow	1
Masked Woodswallow	1
Australian Magpie	1
Australian Raven	1
Magpie-lark	1
Red-capped Robin	1
Mistletoebird	1

Site: 'Mia Mia' Waterhole

	2016	2016	2016
English Name	**MIAMO**	**MIAMR**	**MIAMS**
Crested Pigeon	0	0.6	0.1
Diamond Dove	0.2	0	0
Peaceful Dove	0	0.6	0
Whistling Kite	0	0.2	0.1
Black Kite	1.2	1.2	1.2
Black Falcon	0	0.2	0
Little Button-quail	0	0	0.2
Galah	0	0.4	0
Little Corella	0	5	0
Blue Bonnet	0.6	0.1	0.2
Budgerigar	0.2	0.2	0.1
Horsfield's Bronze-Cuckoo	0	0.2	0
White-winged Fairy-wren	0	0	1.4
Variegated Fairy-wren	0	0.1	0.8
Red-browed Pardalote	0.2	0	0
White-plumed Honeyeater	1.4	7.8	1.8
Yellow-throated Miner	0.2	0	0
Spiny-cheeked Honeyeater	0	1.2	0
Chestnut-crowned Babbler	0	0.1	0
Chirruping Wedgebill	0	0.4	0.2
Rufous Whistler	0.1	0.2	0
White-breasted Woodswallow	0	0.4	0
Masked Woodswallow	0.4	4	9
White-browed Woodswallow	0	0	0.4
Black-faced Woodswallow	1	0	0
Willie Wagtail	0.2	1.2	0
Australian Raven	0.1	0.2	0
Magpie-lark	0.2	0.4	0
Rufous Songlark	0	0.8	0
White-backed Swallow	0.2	1.2	0
Fairy Martin	0	0.4	0
Tree Martin	0	0.4	0
Mistletoebird	0.1	0.6	0
Zebra Finch	8.2	5.2	2.8
Abun	**14.5**	**33.3**	**18.3**
Rich	**16**	**27**	**13**

'Mia Mia' Waterhole (cont.) – Additional species

English Name	MIAM16
Tawny Frogmouth	1
Australian Owlet-nightjar	1
White-faced Heron	1
Brown Falcon	1
Black-fronted Dotterel	1
Black-faced Cuckoo-shrike	1
White-winged Triller	1
Australian Magpie	1
Little Crow	1

Site: Mona Downs Waterhole

	2015	2016	2015	2016	2015	2016
English Name	**MONAO**	**MONAO**	**MONAR**	**MONAR**	**MONAS**	**MONAS**
Crested Pigeon	0	0	0.8	1	0	0.4
Diamond Dove	0.2	0.2	0	0	0	0
Peaceful Dove	0	0	0	0	0	0.1
Black Kite	0	0	0	0.2	0	0
Galah	0	0	0	4.4	0.1	0.8
Little Corella	0	0	0	0	0.4	0
Cockatiel	0	0	0	0.4	0	0
Blue Bonnet	0	0	0.4	0.4	0.4	0.2
Budgerigar	0	0	0.1	6.6	0	0.4
Red-backed Kingfisher	0	0	0	0.2	0	0
White-winged Fairy-wren	0.1	0	0	0	0	0
Variegated Fairy-wren	0	0	0	0	0.8	0
Red-browed Pardalote	0	0	0	0.1	0	0
White-plumed Honeyeater	0.1	0.2	3.8	2.8	2.4	4.8
Yellow-throated Miner	0	0	0	0	0	0.4
Crimson Chat	0	0.8	0	0	0	0
Chestnut-crowned Babbler	0	0	0	1.4	0	1
Chirruping Wedgebill	0	0	0.1	0.1	0	0.1
Grey Shrike-thrush	0	0	0	0	0	0.2
White-breasted Woodswallow	0	0	0.2	0	0	0
Black-faced Woodswallow	0	0	0	1.2	0	0
Australian Magpie	0	0.1	0	0	0	0.2
Willie Wagtail	0	0.1	0.8	0	0.4	0.4

	2015	2016	2015	2016	2015	2016
English Name	**MONAO**	**MONAO**	**MONAR**	**MONAR**	**MONAS**	**MONAS**
Australian Raven	0	0	0.2	0.4	0.8	0.2
Magpie-lark	0	0	0.1	0	0.2	0
White-backed Swallow	0	0	0.4	0.2	0	0.2
Fairy Martin	0	0	0	0.4	0	0
Tree Martin	0.2	0.4	0.8	1.2	0	0
Mistletoebird	0	0	0	0.2	0	0.4
Zebra Finch	0	0.1	0.8	1.8	0	0.4
Australasian Pipit	0.1	0.4	0	0	0	0
Abun	**0.7**	**2.3**	**8.5**	**23.0**	**5.5**	**10.2**
Rich	**5**	**8**	**12**	**18**	**8**	**16**

Mona Downs Waterhole (cont.) – Additional species

English Name	MONA15	MONA16
Australian Wood Duck	1	0
Pink-eared Duck	1	1
Grey Teal	1	1
Common Bronzewing	1	0
Spotted Nightjar	0	1
Australian Owlet-nightjar	1	1
Whistling Kite	1	1
Wedge-tailed Eagle	1	0
Brown Falcon	0	1
Black Falcon	1	0
Black-fronted Dotterel	1	1
Horsfield's Bronze-Cuckoo	0	1
Striated Pardalote	0	1
Spiny-cheeked Honeyeater	1	0
Orange Chat	1	0
Black-faced Cuckoo-shrike	1	1
Masked Woodswallow	0	1
White-browed Woodswallow	0	1
Little Crow	1	0

Site Pandie Pandie Waterhole

	2014	2014
English Name	**PANDD**	**PANDR**
Crested Pigeon	0.1	0.4
Peaceful Dove	0	0.1
Whistling Kite	0	0.2
Brown Falcon	0.2	0
Red-tailed Black-Cockatoo	0	0.2
White-winged Fairy-wren	1	0
White-plumed Honeyeater	0	2.4
Yellow-throated Miner	0	0.4
Spiny-cheeked Honeyeater	0	0.2
Grey Shrike-thrush	0	0.6
White-breasted Woodswallow	0	0.4
Masked Woodswallow	0.4	0.8
White-browed Woodswallow	0	0.4
Black-faced Woodswallow	0	0.6
Grey Fantail	0	0.2
Willie Wagtail	0.2	0.4
Australian Raven	0	0.2
Magpie-lark	0	0.1
White-backed Swallow	0	0.4
Fairy Martin	0	0.8
Mistletoebird	0	0.1
Abun	**1.9**	**8.9**
Rich	**5**	**19**

Pandie Pandie Waterhole (cont.) – Additional species

English Name	**ANDR14**
Diamond Dove	1
Australian Owlet-nightjar	1
Australian Pelican	1
White-necked Heron	1
White-faced Heron	1
Black Kite	1
Collared Sparrowhawk	1
Spotted Harrier	1
Caspian Tern	1

English Name	ANDR14
Galah	1
Little Corella	1
Blue Bonnet	1
Red-rumped Parrot	1
Budgerigar	1
Southern Boobook	1
Red-browed Pardalote	1
Striated Pardalote	1
White-browed Babbler	1
Black-faced Cuckoo-shrike	1
Australian Magpie	1
Little Crow	1
Tree Martin	1
Zebra Finch	1

Site: Pelican Waterhole

	2016	2016	2016
English Name	**PELID**	**PELIO**	**PELIR**
Crested Pigeon	0	0.2	0.4
Whistling Kite	0	0	0.4
Black Kite	0	0	1.4
Galah	0	0	0.4
Little Corella	0	0	0.4
Red-rumped Parrot	0	0	0.6
Budgerigar	0	0.8	0
Horsfield's Bronze-Cuckoo	0.6	0	0
Pallid Cuckoo	0.2	0	0
Red-backed Kingfisher	0.2	0	0.4
White-winged Fairy-wren	0	0.1	0
Red-browed Pardalote	0.2	0	0.1
White-plumed Honeyeater	0.2	0	2.8
Black-faced Cuckoo-shrike	0	0	0.2
Grey Shrike-thrush	0	0	0.4
White-breasted Woodswallow	0	0	0.8
Masked Woodswallow	1	0	0
Black-faced Woodswallow	0.1	0.2	0.2
Willie Wagtail	1	0	0.6

	2016	2016	2016
English Name	**PELID**	**PELIO**	**PELIR**
Australian Raven	0	0	0.2
Magpie-lark	0	0	0.2
White-backed Swallow	0.8	0	0.4
Fairy Martin	1.2	0.8	6.2
Tree Martin	0	0	0.6
Zebra Finch	0.4	0	0.4
Australasian Pipit	0.4	0.2	0
Abun	**6.3**	**2.3**	**17.1**
Rich	**12**	**6**	**20**

Pelican Waterhole (cont.) – Additional species

English Name	PELI16
Plumed Whistling-Duck	1
Australian Wood Duck	1
Pink-eared Duck	1
Grey Teal	1
Pacific Black Duck	1
Diamond Dove	1
White-necked Heron	1
Eastern Great Egret	1
White-faced Heron	1
Straw-necked Ibis	1
Yellow-billed Spoonbill	1
Brolga	1
Black-winged Stilt	1
Red-capped Plover	1
Black-fronted Dotterel	1
Red-kneed Dotterel	1
Banded Lapwing	1
Masked Lapwing	1
Australian Pratincole	1
Gull-billed Tern	1
Variegated Fairy-wren	1
Striated Pardalote	1
Yellow-throated Miner	1
Orange Chat	1

English Name	PELI16
White-winged Triller	1
Australian Magpie	1
Little Crow	1

Site: Peraka Lakes Channel

	2016	2016	2016
English Name	**PERAD**	**PERAO**	**PERAR**
Crested Pigeon	0.2	0	0
Diamond Dove	0	0	0.4
Whistling Kite	0	0	0.4
Black Kite	0.2	0.1	0.2
Galah	0.2	0	2
Budgerigar	0	0	3.2
Horsfield's Bronze-Cuckoo	0	0.2	0.2
Pallid Cuckoo	0.2	0	0
Red-backed Kingfisher	0	0.1	0.2
White-winged Fairy-wren	0	1.4	0
Variegated Fairy-wren	0	1	0
Red-browed Pardalote	0.2	0	0.1
White-plumed Honeyeater	0.4	0	2.8
Black-faced Cuckoo-shrike	0.2	0	0
Rufous Whistler	0.4	0	0
Grey Shrike-thrush	0	0	0.2
Willie Wagtail	0.6	0.4	0.8
Australian Raven	0	0	0.4
Restless Flycatcher	0	0	0.2
Magpie-lark	0	0.1	0
Fairy Martin	0.8	1.2	1.4
Tree Martin	0	0	1
Zebra Finch	0.8	1.2	2
Abun	**4.2**	**5.7**	**15.5**
Rich	**11**	**9**	**16**

Peraka Lakes Channel (cont.) – Additional species

English Name	PERA16
Plumed Whistling-Duck	1
Pink-eared Duck	1
Grey Teal	1
Pacific Black Duck	1
Hardhead	1
Blue-billed Duck	1
Hoary-headed Grebe	1
Peaceful Dove	1
Spotted Nightjar	1
Australian Owlet-nightjar	1
White-necked Heron	1
Nankeen Night-Heron	1
Yellow-billed Spoonbill	1
Wedge-tailed Eagle	1
Nankeen Kestrel	1
Brown Falcon	1
Australian Hobby	1
Australian Spotted Crake	1
Red-necked Avocet	1
Black-fronted Dotterel	1
Gull-billed Tern	1
Little Corella	1
Cockatiel	1
Eastern Barn Owl	1
Striated Pardalote	1
White-winged Triller	1
White-breasted Woodswallow	1
Masked Woodswallow	1
Black-faced Woodswallow	1
Australian Magpie	1
Little Crow	1
Red-capped Robin	1
Australian Reed-Warbler	1
Little Grassbird	1
Rufous Songlark	1
Brown Songlark	1
White-backed Swallow	1

English Name	PERA16
Welcome Swallow	1
Mistletoebird	1
Australasian Pipit	1

Site: Poonarunna Bore

	2014	2014	2014
English Name	**POOND**	**POONF**	**POONR**
Crested Pigeon	0	1.4	1.4
Diamond Dove	0	0.1	0.2
Peaceful Dove	0	0.4	0
Galah	0	1.4	0.4
Little Corella	0	0	0.8
Blue Bonnet	0	0.4	0.4
Horsfield's Bronze-Cuckoo	0	0.1	0.1
White-winged Fairy-wren	0.1	0	0
Variegated Fairy-wren	0	1.6	1
Red-browed Pardalote	0	0.4	0
Striated Pardalote	0	0.6	0
White-plumed Honeyeater	0.1	3.2	2.4
Yellow-throated Miner	0	0.1	0.4
Spiny-cheeked Honeyeater	0	0.6	0.4
Chestnut-crowned Babbler	0	0.1	0
Chirruping Wedgebill	0	0	0.4
Black-faced Cuckoo-shrike	0	0.4	0.4
White-breasted Woodswallow	0	0.4	0.4
Black-faced Woodswallow	0.1	0.2	1
Grey Fantail	0	0	0.2
Willie Wagtail	0.1	1.2	0.6
Australian Raven	0	0.1	0.6
Little Crow	0	0.2	0
Magpie-lark	0	0	0.1
White-backed Swallow	0.6	0.8	0.4
Fairy Martin	0	0.2	0
Tree Martin	0	2.4	0
Mistletoebird	0	0.2	0.6
Zebra Finch	0.1	0	0.6
Abun	**1.1**	**16.5**	**12.8**
Rich	**6**	**23**	**21**

Poonarunna Bore (cont.) – Additional species

English Name	
Australian Shelduck	1
Pink-eared Duck	1
Grey Teal	1
Pacific Black Duck	1
Hardhead	1
Hoary-headed Grebe	1
Little Pied Cormorant	1
Little Black Cormorant	1
Eurasian Coot	1
Black-winged Stilt	1
Red-necked Avocet	1
Black-fronted Dotterel	1
Masked Lapwing	1
Caspian Tern	1
Budgerigar	1
Red-backed Kingfisher	1
Cinnamon Quail-thrush	1
Masked Woodswallow	1
Australian Magpie	1
Red-capped Robin	1
Australian Reed-Warbler	1
Little Grassbird	1

Site: Stony Point Waterhole

	2014	2015	2014	2015	2014	2015	2014	2015
English Name	**STONG**	**STONG**	**STONO**	**STONO**	**STONR**	**STONR**	**STONS**	**STONS**
Common Bronzewing	0	0	0.4	0.2	0	0.2	0	0
Crested Pigeon	0	0	0.4	1.6	1.4	0.6	0.6	0.1
Diamond Dove	0	0	0	1.4	0	0.4	0	0.8
Whistling Kite	0	0	0	0	0	0.4	0	0
Australian Hobby	0	0.1	0	0	0	0.2	0	0
Galah	0	0	0	0	0.6	0.6	0	0
Little Corella	0	0	0	0.2	0	0.8	0	0
Blue Bonnet	0	0	0	0	1.6	0.4	0	0.1
Budgerigar	0	0	0	0.1	0	0.4	0	0
Horsfield's Bronze-Cuckoo	0	0	0	0.2	0	0	0	0

	2014	2015	2014	2015	2014	2015	2014	2015
English Name	**STONG**	**STONG**	**STONO**	**STONO**	**STONR**	**STONR**	**STONS**	**STONS**
Red-backed Kingfisher	0	0	0	0.2	0	0	0	0
Variegated Fairy-wren	0	0	0	0	1	2.4	0.8	0
Red-browed Pardalote	0	0	0	0.1	0	0	0	0
Striated Pardalote	0	0	0	0	0.2	0.1	0	0
White-plumed Honeyeater	0	0	0.6	3	3.4	4.4	0.8	2.4
Yellow-throated Miner	0	0	0	0	0.2	0.1	0	0
Spiny-cheeked Honeyeater	0	0	0	0	0.8	1.2	0	0
Painted Honeyeater	0	0	0	0.1	0	0	0	0
Chestnut-crowned Babbler	0	0	0	0	1.2	0.4	0.8	0.1
Chirruping Wedgebill	0	0	0.2	0	0.4	0.4	0	0.1
Black-faced Cuckoo-shrike	0	0	0	0	0.2	0.2	0	0
White-breasted Woodswallow	0	0	0	0.4	1	0	0	0
Masked Woodswallow	0	0	0	0	0.4	0	0	0
White-browed Woodswallow	0	0	0	0	0.2	0	0	0
Black-faced Woodswallow	0	0	0	1.6	0.4	0	0.4	0.4
Willie Wagtail	0	0	0	0.2	1	0.6	0.4	0.1
Australian Raven	0	0	0	0	0.2	0.4	0.1	0
Magpie-lark	0	0	0	0.4	0.8	1	0	0
Rufous Songlark	0	0	0	0.2	0	0	0	0.2
White-backed Swallow	0.2	0.1	0.4	0	0.8	0.6	0.4	0.4
Tree Martin	0	0	0	1.2	2	0	0	0.4
Mistletoebird	0	0	0	0	0.2	0.4	0	0
Zebra Finch	0	0.1	0	3.4	0	7	0	0
Abun	**0.2**	**0.3**	**2.0**	**14.5**	**18.0**	**23.2**	**4.3**	**5.1**
Rich	**1**	**3**	**5**	**17**	**21**	**23**	**8**	**11**

Stony Point Waterhole (cont.) – Additional species

English Name	**STON14**	**STON15**
Pink-eared Duck	0	1
Grey Teal	0	1
Hardhead	0	1
Hoary-headed Grebe	1	1
Spotted Nightjar	0	1
Australian Owlet-nightjar	1	1
Great Cormorant	0	1
White-faced Heron	1	1

English Name	STON14	STON15
Nankeen Kestrel	0	1
Black-winged Stilt	0	1
Black-fronted Dotterel	1	1
Common Greenshank	0	1
Caspian Tern	1	0
Cockatiel	0	1
Pallid Cuckoo	0	1
White-winged Fairy-wren	0	1
Crimson Chat	0	1
White-winged Triller	0	1
Australian Magpie	0	1
Little Crow	0	1
Fairy Martin	0	1

Site: Tepamimi Waterhole

	2015	2014	2015	2015	2014	2015
English Name	**TEPAD**	**TEPAO**	**TEPAO**	**TEPAP**	**TEPAR**	**TEPAR**
Crested Pigeon	0.8	0	0	0	0.8	0.1
Diamond Dove	0.4	0	0	0	0	0.1
Peaceful Dove	0	0	0	0	0.4	0
Whistling Kite	0	0	0	0	0.2	0.2
Collared Sparrowhawk	0.2	0	0	0	0	0
Nankeen Kestrel	0	0	0.2	0.2	0	0.4
Black Falcon	0	0	0	0.1	0	0
Galah	0	0	0	0	0.4	0.1
Little Corella	0	0	0.1	0	0	0
Red-backed Kingfisher	0	0	0	0	0	0.2
White-winged Fairy-wren	0.4	1	0.8	4	0	0
Variegated Fairy-wren	0	0	0.6	1.2	0	0
Grey Grasswren	0	0	0	1	0	0
White-plumed Honeyeater	0.4	0	0	0	2.4	2.4
Spiny-cheeked Honeyeater	0.1	0	0	0	0	0
Crimson Chat	0.6	0	0	0	0	0.2
Orange Chat	0	0	0.4	0	0	0
Black-faced Cuckoo-shrike	0	0	0	0	0	0.4
White-breasted Woodswallow	0.4	0	0	0.4	0.1	0.1
Black-faced Woodswallow	0	0.6	0.1	0	0.8	0

	2015	2014	2015	2015	2014	2015
English Name	**TEPAD**	**TEPAO**	**TEPAO**	**TEPAP**	**TEPAR**	**TEPAR**
Willie Wagtail	0	0.6	0.6	1	1	1
Australian Raven	0	0	0	0	1.2	0.4
Magpie-lark	0	0.4	0	0	1.2	1
Red-capped Robin	0	0	0	0.2	0	0
Australian Reed-Warbler	0	0.2	0	0	0	0.1
White-backed Swallow	0.2	0	0	0	0	0
Fairy Martin	0	0	0	0	2.4	1
Tree Martin	0.4	0	0	0	0	2.4
Mistletoebird	0	0	0	0	0	0.2
Zebra Finch	0	0	0	0.4	0	0
Abun	**3.9**	**2.8**	**2.8**	**8.5**	**10.9**	**10.3**
Rich	**10**	**5**	**7**	**9**	**11**	**17**

Tepamimi Waterhole (cont.) – Additional species

English Name	**TEPA14**	**TEPA15**
Plumed Whistling-Duck	1	0
Black Swan	1	0
Australian Wood Duck	1	1
Pink-eared Duck	1	1
Grey Teal	1	1
Pacific Black Duck	1	1
Hardhead	1	1
Australasian Grebe	0	1
Hoary-headed Grebe	0	1
Australasian Darter	1	1
Great Cormorant	0	1
Little Black Cormorant	1	1
Pied Cormorant	1	1
Australian Pelican	1	1
White-necked Heron	1	1
White-faced Heron	1	1
Nankeen Night-Heron	1	0
Royal Spoonbill	0	1
Yellow-billed Spoonbill	1	1
Black Kite	1	1
Spotted Harrier	0	1

English Name	TEPA14	TEPA15
Swamp Harrier	0	1
Wedge-tailed Eagle	0	1
Brown Falcon	1	1
Australian Spotted Crake	0	1
Black-tailed Native-hen	1	0
Eurasian Coot	1	1
Australian Bustard	1	0
Red-necked Avocet	1	1
Black-fronted Dotterel	1	1
Red-kneed Dotterel	1	1
Masked Lapwing	0	1
Sharp-tailed Sandpiper	1	0
Little Button-quail	0	1
Cockatiel	0	1
Blue Bonnet	1	0
Horsfield's Bronze-Cuckoo	0	1
Striated Pardalote	1	0
Singing Honeyeater	0	1
Yellow-throated Miner	1	0
Masked Woodswallow	0	1
White-browed Woodswallow	0	1
Australian Magpie	1	0
Little Crow	0	1
Little Grassbird	1	0
Welcome Swallow	1	1

Site: 'Tinnie Landing' Waterhole

	2016	2016	2016
English Name	**TINND**	**TINNO**	**TINNR**
Crested Pigeon	0	0.1	1.6
Diamond Dove	0.1	0.1	3.2
Whistling Kite	0	0	0.2
Black Kite	0.1	0.4	1.2
Wedge-tailed Eagle	0.1	0	0
Black Falcon	0	0	0.1
Galah	0.1	0	0.4
Little Corella	0	0	0.1

	2016	2016	2016
English Name	**TINND**	**TINNO**	**TINNR**
Blue Bonnet	0	0.1	0
Budgerigar	0	0	3
Red-backed Kingfisher	0	0	0.1
White-winged Fairy-wren	3	0	0
Variegated Fairy-wren	0	0	3.2
Red-browed Pardalote	0	0	0.1
Singing Honeyeater	0.1	0	0
White-plumed Honeyeater	0.2	0.4	7.8
Yellow-throated Miner	0	0	1.4
Spiny-cheeked Honeyeater	0	0	0.1
Chirruping Wedgebill	0	0	1.2
Black-faced Cuckoo-shrike	0	0.1	1.2
Rufous Whistler	0	0.1	0
White-breasted Woodswallow	0	0	2
Black-faced Woodswallow	0.2	0.4	0
Willie Wagtail	0.4	0	0.8
Magpie-lark	0	0	0.4
White-backed Swallow	0.8	0	0.6
Tree Martin	0	0.6	3
Mistletoebird	0	0	0.2
Zebra Finch	26.2	0.1	2
Abun	**31.3**	**2.4**	**33.9**
Rich	**11**	**10**	**23**

'Tinnie Landing' Waterhole (cont.) – Additional species

English Name	**TINN16**
Australian Wood Duck	1
Pink-eared Duck	1
Grey Teal	1
Pacific Black Duck	1
Hoary-headed Grebe	1
Crested Pigeon	1
Tawny Frogmouth	1
Australian Owlet-nightjar	1
Australian Pelican	1
White-faced Heron	1

English Name	TINN16
Little Eagle	1
Black-winged Stilt	1
Red-necked Avocet	1
Red-capped Plover	1
Black-fronted Dotterel	1
Banded Lapwing	1
Curlew Sandpiper	1
Gull-billed Tern	1
Caspian Tern	1
Whiskered Tern	1
Horsfield's Bronze-Cuckoo	1
Australian Magpie	1
Australian Raven	1
Little Crow	1

Site: Tippipilla Waterhole

	2016	2016
English Name	**TIPPD**	**TIPPR**
Diamond Dove	1.6	0.8
Black Kite	0.2	0
Nankeen Kestrel	0.2	0
Budgerigar	11.8	4.6
Horsfield's Bronze-Cuckoo	0.4	0.1
Pallid Cuckoo	0	0.1
Red-backed Kingfisher	0.2	0.2
White-winged Fairy-wren	0.4	0
Variegated Fairy-wren	0.6	0.6
Red-browed Pardalote	0.2	0.1
Singing Honeyeater	0	0.1
White-plumed Honeyeater	1.8	3.6
Yellow-throated Miner	0.1	0
Crimson Chat	0.2	0
Chestnut-crowned Babbler	0	0.2
White-winged Triller	0.8	0
Masked Woodswallow	0	0.8
Black-faced Woodswallow	0.8	0.6
Willie Wagtail	0.2	0.2

	2016	2016
English Name	**TIPPD**	**TIPPR**
Australian Raven	0.2	0.4
Red-capped Robin	0.4	0
White-backed Swallow	0	1
Fairy Martin	2	4.2
Tree Martin	0.6	1.6
Mistletoebird	0	0.2
Zebra Finch	1.2	2.6
Abun	**23.9**	**22.0**
Rich	**20**	**19**

Tippipilla Waterhole (cont.) – Additional species

English Name	TIPP16
Brown Quail	1
Plumed Whistling-Duck	1
Grey Teal	1
Brolga	1
Black-winged Stilt	1
Red-necked Avocet	1
Black-fronted Dotterel	1
Banded Lapwing	1
Eastern Barn Owl	1
Cinnamon Quail-thrush	1
Australian Magpie	1
Little Crow	1
Magpie-lark	1
Rufous Songlark	1
Australasian Pipit	1

Site: Ultomurra Waterhole

	2015	2016	2014	2015	2016	2015	2016	2014	2015	2016
English Name	**ULTOD**	**ULTOD**	**ULTOO**	**ULTOO**	**ULTOO**	**ULTOP**	**ULTOP**	**ULTOR**	**ULTOR**	**ULTOR**
Crested Pigeon	0	0.1	0.2	0	0.2	0	0.4	0.1	0.4	0.6
Diamond Dove	0	0	0	0.4	0.4	0	0	0.2	0.2	1
Peaceful Dove	0	0	0.1	0	0	0	0	0.1	0	0.2
Whistling Kite	0	0	0	0	0	0	0	0	0.2	0.4
Black Kite	0	0.2	0	0	0	0	0.4	0	0	0.4
Little Eagle	0	0	0	0	0	0	0	0	0	0.2
Nankeen Kestrel	0	0.2	0	0	0	0	0.4	0	0	0
Galah	0	0	0.8	0.1	0	0	0	1	1.2	1.8
Little Corella	0	0.1	0	0	0	0	0	0	0	0.6
Budgerigar	0	0.8	0	0	1.6	0	2.6	0	1.6	2.4
Horsfield's Bronze-Cuckoo	0	0.6	0	0	0	0	0.2	0	0	0
Pallid Cuckoo	0	0.2	0	0	0	0	0	0	0	0
Red-backed Kingfisher	0	0	0	0	0.2	0	0	0	0	0
Sacred Kingfisher	0	0	0	0	0	0	0	0	0	0.2
White-winged Fairy-wren	1	3	0	0	0	0.8	0.6	0	0	0
Variegated Fairy-wren	0	0.6	0	0	0	0	1	1.2	0.8	0
Eyrean Grasswren	0.6	1.8	0	0	0	0	0	0	0	0
Red-browed Pardalote	0	0.1	0	0	0	0	0.1	0	0	0
White-plumed Honeyeater	0	0.2	1.8	0.8	2	0.1	0.4	3.6	3.2	6
Yellow-throated Miner	0	0.1	0.1	0	0.2	0	0	0.6	0.4	0.4
Spiny-cheeked Honeyeater	0	0	0	0	0	0	0	0.2	0	0.6
Crimson Chat	0	0.4	0	0	0	0	0.4	0	0	0

	2015	2016	2014	2015	2016	2015	2016	2014	2015	2016
English Name	**ULTOD**	**ULTOD**	**ULTOO**	**ULTOO**	**ULTOO**	**ULTOP**	**ULTOP**	**ULTOR**	**ULTOR**	**ULTOR**
Chestnut-crowned Babbler	0	0	0	0	0	0.1	0	0	0	0
Chirruping Wedgebill	0	0	0	0	0	0.1	0.2	0	0	0
Black-faced Cuckoo-shrike	0	0.1	0	0.1	0	0	0	0	0.4	0
White-winged Triller	0	0	0	0	0	0	0	0	0	0.2
Rufous Whistler	0	0	0	0	0	0	0.2	0	0	0
Grey Shrike-thrush	0	0	0	0	0	0	0	0.6	0.2	0.4
Masked Woodswallow	0	2.2	0	0	0	0	0	0	0	0
Black-faced Woodswallow	0	0	0	0	0	0	0.1	0	0	0
Willie Wagtail	0.2	0	0	0	0	0	0.2	0.4	0.6	0.6
Australian Raven	0	0	0	0	0	0	0	0.2	0	0
Little Crow	0	0.1	0	0	0	0	0	0	0	0
Magpie-lark	0	0	0	0	0	0	0	0	0.2	0.6
Rufous Songlark	0	0	0	0	0	0	0	0	0	0.4
White-backed Swallow	0	0	0.4	0	0.4	0	0	0.8	0.4	0.4
Fairy Martin	0	0.2	0	0	1.6	0	0	0	0	2
Tree Martin	0	0	0	0	0.8	0	0	0.4	0.4	1.2
Mistletoebird	0	0	0.1	0	0	0	0	0.4	0.2	0.2
Zebra Finch	2	3	0	0	0	0.2	0.8	0	0	0.4
Abun	**3.8**	**14.0**	**3.5**	**1.4**	**7.4**	**1.3**	**8.0**	**9.8**	**10.4**	**21.2**
Rich	**4**	**19**	**7**	**4**	**9**	**5**	**15**	**14**	**15**	**23**

Ultomurra Waterhole (cont.) – Additional species

English Name	ULTO14	ULTO15	ULTO16
Brown Quail	0	0	1
Plumed Whistling-Duck	0	0	1
Australian Wood Duck	0	0	1
Pink-eared Duck	0	0	1
Grey Teal	0	0	1
Spotted Nightjar	1	0	1
Australian Owlet-nightjar	1	1	1
Australasian Darter	0	0	1
Great Cormorant	0	0	1
Little Black Cormorant	0	0	1
Pied Cormorant	0	0	1
Australian Pelican	0	1	0
White-necked Heron	0	1	1
White-faced Heron	1	1	1
Collared Sparrowhawk	0	1	0
Australian Bustard	0	0	1
Black-fronted Dotterel	1	1	1
Banded Lapwing	0	0	1
Masked Lapwing	0	1	0
Cockatiel	0	1	1
Blue Bonnet	1	1	1
Channel-billed Cuckoo	0	0	1
Southern Boobook	0	1	0
Singing Honeyeater	1	0	0
White-breasted Woodswallow	0	1	1

Site: Wadlarkaninna Waterhole

	2016	2014	2016	2014	2016	2014	2016
English Name	**WADLD**	**WADLO**	**WADLO**	**WADLR**	**WADLR**	**WADLS**	**WADLS**
Common Bronzewing	0	0.2	0	0.2	0	0.2	0
Crested Pigeon	0.1	0.2	0	1	0.2	0.6	0.4
Diamond Dove	0.8	0.4	0.4	0	2	0	1.6
Peaceful Dove	0	0	0	0.6	0.4	0.2	0.8
Black Kite	0.4	0	0	0	0.1	0	1.6
Galah	0	1	0.8	1.6	0.1	0.4	0.4
Little Corella	0	0.4	0.4	1.2	0.8	0	2.4
Blue Bonnet	0.4	1.2	0	0.4	0.6	0.4	0.8
Budgerigar	2	0	0.8	0	0.2	0	2
Horsfield's Bronze-Cuckoo	0.2	0.1	0	0.2	0	0.4	0
Red-backed Kingfisher	0	0	0.2	0.2	0.2	0	0.4
White-winged Fairy-wren	2	0	0	0	0	0	0.1
Variegated Fairy-wren	0	0	1.2	0	0	0	1.2
Eyrean Grasswren	1	0	0	0	0	0	0
Red-browed Pardalote	0.1	0.2	0.1	0	0.2	0.1	0
Striated Pardalote	0	0	0	0	0	0.2	0
Singing Honeyeater	0.2	0	0	0	0	0	0
White-plumed Honeyeater	0.2	2	0.8	2.4	4.6	5	6.4
Yellow-throated Miner	0	0	0	0	0	0.1	0
Spiny-cheeked Honeyeater	0.2	0	0	0.4	0.2	0.8	0.2
Crimson Chat	0	0	0	0	0	0.4	0
Black Honeyeater	0	0	0	0	0	0.2	0

	2016	2014	2016	2014	2016	2014	2016
English Name	**WADLD**	**WADLO**	**WADLO**	**WADLR**	**WADLR**	**WADLS**	**WADLS**
Chestnut-crowned Babbler	0.8	0.6	0	0	0.1	0.1	0.1
Chirruping Wedgebill	0	0.2	0.1	0.4	0.1	0.6	0.8
Black-faced Cuckoo-shrike	0.4	0	0	0.2	0.8	0	0.6
Rufous Whistler	0.2	0	0.2	0	0.1	0	0
White-breasted Woodswallow	0	0	0	0.4	0	0.4	1
Black-faced Woodswallow	1.6	0	0	1.2	1.4	0.6	0.8
Willie Wagtail	0.2	0.2	0	1	0.6	1.6	0.6
Australian Raven	0	0	0	0.1	0	0.1	0.8
Magpie-lark	0	0	0	0	0	0.2	0.6
Rufous Songlark	0	0	0	0	0.2	0	0
Brown Songlark	0	0	0	0	0	0	0.4
White-backed Swallow	0.6	0.6	0.4	0	0.4	0.4	0.2
Tree Martin	0	0.4	0	0.8	1.6	0.4	1.4
Mistletoebird	0	0	0	0	0	0.4	0
Zebra Finch	3.2	0.8	2	0	1.6	0	2.4
Abun	**14.6**	**8.5**	**7.4**	**12.3**	**16.5**	**13.8**	**28.0**
Rich	**19**	**15**	**12**	**17**	**22**	**23**	**25**

Wadlarkaninna Waterhole (cont.) – Additional species

English Name	WADL14	WADL16
Australian Wood Duck	0	1
Pink-eared Duck	0	1
Grey Teal	0	1
Hoary-headed Grebe	1	1
Flock Bronzewing	0	1
Australian Owlet-nightjar	1	1
White-necked Heron	0	1
White-faced Heron	1	1
Spotted Harrier	1	1
Wedge-tailed Eagle	0	1
Little Eagle	0	1
Brown Falcon	1	0
Red-necked Avocet	1	0
Black-fronted Dotterel	1	1
Pallid Cuckoo	0	1
White-winged Triller	1	0
Masked Woodswallow	1	1
White-browed Woodswallow	1	0
Australian Magpie	1	1
Little Crow	1	1
Fairy Martin	1	0
Australasian Pipit	0	1

Site: Yammakira Waterhole

	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2015
English Name	**YAMMD**	**YAMMD**	**YAMMF**	**YAMMF**	**YAMMH**	**YAMMH**	**YAMMO**	**YAMMO**	**YAMMR**	**YAMMR**	**YAMMS**
Crested Pigeon	0	0	0	0	0.4	0	0.2	0	0.6	0.8	0.4
Peaceful Dove	0.2	0	0	0	0	0	0	0	0.1	0	0.2
Whistling Kite	0	0	0	0	0	0	0	0	0.1	0.4	0.2
Nankeen Kestrel	0	0	0	0	0	0	0	0.2	0	0	0
Galah	0	0	0	0	0	0	0	0	0.6	0.4	0
Little Corella	0	0	0	0	0	0	0	0	0	0.1	0
Red-rumped Parrot	0	0	0	0	0	0	0	0	0.4	0.4	0
Horsfield's Bronze-Cuckoo	0	0	0	0	0	0	0	0	0.2	0	0
White-winged Fairy-wren	0.6	0	0	0	1	0.1	0.1	0	0	0	0
Variegated Fairy-wren	0	0.1	0	0	0	0.8	0.6	0.1	0	0	0
White-plumed Honeyeater	0.1	0	0	0	2	0.8	0.4	0.2	2.2	2.6	4.2
Yellow-throated Miner	0	0	0	0	0	0	0	0	0.4	0.1	1
Spiny-cheeked Honeyeater	0	0	0	0	0	0	0	0	0.1	0	0.2
Painted Honeyeater	0	0	0	0	0	0.1	0	0	0	0	0
Black-faced Cuckoo-shrike	0	0	0	0	0	0	0	0	0	0.2	0
Grey Shrike-thrush	0	0	0	0	0	0	0	0	0.6	0.2	0.1
White-breasted Woodswallow	0	0	0	0	0	0	0	0.2	0.4	0	0.4
Black-faced Woodswallow	0.1	0.2	0	0	0.2	1	0	0	0.8	0	0.2
Australian Magpie	0	0	0	0	0	0	0.2	0	0	0.4	0
Willie Wagtail	0	0	0	0.2	0	0.4	0	0	0.4	0.4	0.2
Australian Raven	0	0	0	0	0	0	0	0	0.4	0.1	0
Magpie-lark	0	0	0	0	0	0	0	0	0.1	0	0

	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2015
English Name	**YAMMD**	**YAMMD**	**YAMMF**	**YAMMF**	**YAMMH**	**YAMMH**	**YAMMO**	**YAMMO**	**YAMMR**	**YAMMR**	**YAMMS**
Red-capped Robin	0	0	0	0	0	0.4	0	0	0	0	0
White-backed Swallow	0.1	0.4	0	0	0.4	0.6	0	0	0.2	0.2	0.8
Fairy Martin	0	0	0	0	0	0	0	0	0	0.4	0
Tree Martin	0	0	0	0	0.2	0	0	0	0.4	0.1	0
Mistletoebird	0	0	0	0	0.2	0.4	0	0	0	0	0.4
Zebra Finch	0	0	0	0	0.8	1.6	0.2	0.2	0.8	0	0.4
Australasian Pipit	0	0	0.1	0	0	0	0	0	0	0	0
Abun	**1.1**	**0.7**	**0.1**	**0.2**	**5.2**	**6.2**	**1.7**	**0.9**	**8.8**	**6.8**	**8.7**
Rich	**5**	**3**	**1**	**1**	**8**	**10**	**6**	**5**	**18**	**15**	**13**

Yammakira Waterhole (cont.) – Additional species

English Name	YAMM14	YAMM15
Emu	1	1
Pink-eared Duck	1	0
Grey Teal	1	0
Pacific Black Duck	0	1
Diamond Dove	1	1
Australian Owlet-nightjar	1	0
Australasian Darter	1	1
Australian Pelican	1	1
White-necked Heron	1	1
White-faced Heron	1	1
Nankeen Night-Heron	0	1
Black-tailed Native-hen	0	1
Black-fronted Dotterel	1	1
Caspian Tern	1	0
Budgerigar	1	1
Southern Boobook	0	1
Eastern Barn Owl	0	1
Red-backed Kingfisher	0	1
Sacred Kingfisher	1	0
Red-browed Pardalote	1	0
Striated Pardalote	1	0
Rufous Whistler	0	1
Little Crow	1	1
Common Starling	1	0

Site: Yellow Waterhole

	2014	2016	2016	2014	2016	2014	2016
English Name	**YELLO**	**YELLO**	**YELLP**	**YELLR**	**YELLR**	**YELLS**	**YELLS**
Crested Pigeon	0	0.4	0.2	0.1	0.2	1	0.6
Diamond Dove	0	0.2	0.2	0.2	0.4	0.2	1.4
Peaceful Dove	0	0	0	0.4	0.2	0.2	0.2
Whistling Kite	0	0	0	0	0.2	0	0
Black Kite	0	0	0	0	0.6	0	0.4
Galah	0	0.1	0	0.2	0.4	0	1
Little Corella	0	0	0.1	0.1	0.8	0	0.8
Cockatiel	0	0.1	0	0	0	0	0.1
Blue Bonnet	0.1	0.4	1.6	0.4	0.4	0.1	0.8
Budgerigar	0	7.2	4	0	5.2	0	2.4
Horsfield's Bronze-Cuckoo	0.2	0	0.2	0	0	0.2	0.2
Red-backed Kingfisher	0	0.2	0	0	0.4	0	0.2
White-winged Fairy-wren	0.8	0	0	0	0	0	0
Variegated Fairy-wren	0	0	0	0.6	0.8	0.6	1.2
Southern Whiteface	0	0	0.1	0	0	0.4	0
Red-browed Pardalote	0	0.1	0.2	0.2	0.2	0.4	0.1
Striated Pardalote	0	0.2	0.4	0	0	0	0
White-plumed Honeyeater	0.6	1.2	1.8	4	6.2	2.2	5.2
Yellow-throated Miner	0.1	0	0.1	0	0.2	0.4	0.4
Spiny-cheeked Honeyeater	0	0	0	0.6	0	0.4	0
Crimson Chat	0.4	0	0	0	0	0	0
Chestnut-crowned Babbler	0	0	0.1	0.4	0	0.8	0.8

	2014	2016	2016	2014	2016	2014	2016
English Name	**YELLO**	**YELLO**	**YELLP**	**YELLR**	**YELLR**	**YELLS**	**YELLS**
Chirruping Wedgebill	0	0	0.2	0.4	0.8	0.6	0.8
Black-faced Cuckoo-shrike	0	0	0	0	0.1	0.1	0.2
White-winged Triller	0.2	0	0	0	0	0	0
Rufous Whistler	0	0.2	0	0	0	0	0
White-breasted Woodswallow	0	0	0	0.4	0.8	0.4	0
Black-faced Woodswallow	0.2	1.2	0.4	0.4	0.4	0.4	0.4
Willie Wagtail	0	0.4	0.4	0.8	0.8	0.6	0.8
Australian Raven	0.1	0	0	0.1	0	0	0.2
Little Crow	0	0	0	0	0	0	0.1
Restless Flycatcher	0	0.2	0	0	0	0	0
Magpie-lark	0	0	0	0.2	0.2	0	0
Rufous Songlark	0	0	0.1	0.2	0.2	0	0
White-backed Swallow	0.8	0.8	0.6	0.4	1	0.4	0
Tree Martin	0	0	0	0	0.6	0	0.8
Mistletoebird	0	0.1	1.2	0.2	0.2	0.2	0.6
Zebra Finch	0	11.6	14.8	0.1	6.4	0	3.8
Abun	**3.5**	**24.6**	**26.7**	**10.4**	**27.7**	**9.6**	**23.5**
Rich	**10**	**17**	**19**	**21**	**25**	**19**	**25**

Yellow Waterhole (cont.) – Additional species

English Name	YELL14	YELL16
Grey Teal	0	1
Tawny Frogmouth	1	0
Australian Owlet-nightjar	1	1
White-necked Heron	0	1
White-faced Heron	0	1
Nankeen Kestrel	0	1
Brown Falcon	0	1
Australian Hobby	0	1
Black-fronted Dotterel	1	1
Eyrean Grasswren	0	1
Pied Honeyeater	1	0
Fairy Martin	0	1

Site: Yelpawaralinna Waterhole

	2015	2015	2015
English Name	**YELPD**	**YELPO**	**YELPR**
Crested Pigeon	0.4	0	0.1
Diamond Dove	0	0.4	1.8
Galah	0	0	1
Little Corella	0	0	0.1
Cockatiel	0	0	0.1
Blue Bonnet	0	0	0.4
Budgerigar	3	0.2	2.2
Red-backed Kingfisher	0	0	0.2
White-winged Fairy-wren	0	0.4	0
White-plumed Honeyeater	1.2	0.2	4.4
Yellow-throated Miner	0	0	0.1
Black-faced Cuckoo-shrike	0.6	0	0.2
Rufous Whistler	0.2	0	0
Black-faced Woodswallow	0	0	0.8
Willie Wagtail	1.6	0	0.4
Australian Raven	0	0	0.2
Magpie-lark	0	0	0.4
White-backed Swallow	0.2	0	0.2
Tree Martin	0	0	0.4
Zebra Finch	15	0	0.4
Abun	**22.2**	**1.2**	**13.4**
Rich	**8**	**4**	**18**

Yelpawaralinna Waterhole (cont.) – Additional species

English Name	YELP15
Plumed Whistling-Duck	1
Australian Wood Duck	1
Pink-eared Duck	1
Grey Teal	1
Hardhead	1
Hoary-headed Grebe	1
Peaceful Dove	1
Australian Owlet-nightjar	1
Great Cormorant	1
Little Black Cormorant	1
Australian Pelican	1
White-necked Heron	1
White-faced Heron	1
Royal Spoonbill	1
Whistling Kite	1
Wedge-tailed Eagle	1
Nankeen Kestrel	1
Australian Hobby	1
Red-necked Avocet	1
Black-fronted Dotterel	1
Horsfield's Bronze-Cuckoo	1
Variegated Fairy-wren	1
Red-browed Pardalote	1
Crimson Chat	1
White-winged Triller	1
White-breasted Woodswallow	1
Australian Magpie	1
Little Crow	1
Red-capped Robin	1
Mistletoebird	1

Appendix 2 Complete Birdlist with scientific names

Taxonomic order follows Christidis & Boles (2008).

Count	**CB08**	**Zone**	**CODE**	**English Name**	**Scientific Name**	**2014**	**2015**	**2016**
1	3	L	B001	Emu	*Dromaius novaehollandiae*	1	2	1
2	11	L	B009	Stubble Quail	*Coturnix pectoralis*	0	1	0
3	12	L	B011	Brown Quail	*Coturnix ypsilophora*	0	1	2
4	21	W	B205	Plumed Whistling-Duck	*Dendrocygna eytoni*	2	3	6
5	23	W	B217	Musk Duck	*Biziura lobata*	1	2	0
6	24	W	B214	Freckled Duck	*Stictonetta naevosa*	1	0	0
7	26	W	B203	Black Swan	*Cygnus atratus*	1	0	1
8	30	W	B207	Australian Shelduck	*Tadorna tadornoides*	1	0	0
9	32	W	B202	Australian Wood Duck	*Chenonetta jubata*	3	7	6
10	33	W	B213	Pink-eared Duck	*Malacorhynchus membranaceus*	5	7	9
11	37	W	B212	Australasian Shoveler	*Anas rhynchotis*	2	1	1
12	39	W	B211	Grey Teal	*Anas gracilis*	5	8	12
13	44	W	B208	Pacific Black Duck	*Anas superciliosa*	4	4	5
14	45	W	B215	Hardhead	*Aythya australis*	4	4	3
15	46	W	B216	Blue-billed Duck	*Oxyura australis*	0	0	1
16	49	W	B061	Australasian Grebe	*Tachybaptus novaehollandiae*	1	1	0
17	51	W	B062	Hoary-headed Grebe	*Poliocephalus poliocephalus*	5	8	4
18	52	W	B060	Great Crested Grebe	*Podiceps cristatus*	0	0	1
19	63	L	B034	Common Bronzewing	*Phaps chalcoptera*	4	6	2
20	65	L	B036	Flock Bronzewing	*Phaps histrionica*	1	0	2
21	66	L	B043	Crested Pigeon	*Ocyphaps lophotes*	15	14	13
22	72	L	B031	Diamond Dove	*Geopelia cuneata*	10	14	13
23	73	L	B030	Peaceful Dove	*Geopelia striata*	10	7	10

Count	CB08	Zone	CODE	English Name	Scientific Name	2014	2015	2016
24	88	L	B313	Tawny Frogmouth	*Podargus strigoides*	1	1	2
25	92	L	B331	Spotted Nightjar	*Eurostopodus argus*	1	2	5
26	96	L	B317	Australian Owlet-nightjar	*Aegotheles cristatus*	9	8	11
27	196	W	B101	Australasian Darter	*Anhinga novaehollandiae*	3	2	3
28	197	W	B100	Little Pied Cormorant	*Microcarbo melanoleucos*	2	0	0
29	198	W	B096	Great Cormorant	*Phalacrocorax carbo*	0	6	3
30	199	W	B097	Little Black Cormorant	*Phalacrocorax sulcirostris*	4	4	3
31	200	W	B099	Pied Cormorant	*Phalacrocorax varius*	3	4	3
32	204	W	B106	Australian Pelican	*Pelecanus conspicillatus*	4	10	3
33	213	W	B189	White-necked Heron	*Ardea pacifica*	7	12	9
34	214	W	B187	Eastern Great Egret	*Ardea modesta*	1	0	2
35	222	W	B188	White-faced Heron	*Egretta novaehollandiae*	9	12	10
36	226	W	B192	Nankeen Night-Heron	*Nycticorax caledonicus*	1	2	1
37	228	W	B178	Glossy Ibis	*Plegadis falcinellus*	0	0	1
38	230	W	B180	Straw-necked Ibis	*Threskiornis spinicollis*	0	0	4
39	229	W	B179	Australian White Ibis	*Threskiornis molucca*	0	1	0
40	231	W	B181	Royal Spoonbill	*Platalea regia*	0	4	4
41	232	W	B182	Yellow-billed Spoonbill	*Platalea flavipes*	3	3	5
42	234	L	B232	Black-shouldered Kite	*Elanus axillaris*	0	0	1
43	241	L	B228	Whistling Kite	*Haliastur sphenurus*	7	14	12
44	243	L	B229	Black Kite	*Milvus migrans*	3	7	14
45	244	L	B221	Brown Goshawk	*Accipiter fasciatus*	0	0	1
46	245	L	B222	Collared Sparrowhawk	*Accipiter cirrocephalus*	2	2	1
47	248	L	B218	Spotted Harrier	*Circus assimilis*	3	2	2
48	249	LW	B219	Swamp Harrier	*Circus approximans*	1	2	1
49	252	L	B224	Wedge-tailed Eagle	*Aquila audax*	1	6	3

Count	**CB08**	**Zone**	**CODE**	**English Name**	**Scientific Name**	**2014**	**2015**	**2016**
50	253	L	B225	Little Eagle	*Hieraaetus morphnoides*	0	1	5
51	254	L	B240	Nankeen Kestrel	*Falco cenchroides*	3	7	7
52	255	L	B239	Brown Falcon	*Falco berigora*	4	3	5
53	256	L	B235	Australian Hobby	*Falco longipennis*	1	4	3
54	258	L	B238	Black Falcon	*Falco subniger*	0	4	2
55	261	W	B177	Brolga	*Grus rubicunda*	1	2	4
56	262	W	B058	Purple Swamphen	*Porphyrio porphyrio*	0	0	1
57	272	W	B049	Australian Spotted Crake	*Porzana fluminea*	0	2	1
58	279	W	B055	Black-tailed Native-hen	*Tribonyx ventralis*	1	1	0
59	281	W	B056	Dusky Moorhen	*Gallinula tenebrosa*	0	1	0
60	282	W	B059	Eurasian Coot	*Fulica atra*	4	3	0
61	283	L	B176	Australian Bustard	*Ardeotis australis*	1	0	1
62	290	W	B146	Black-winged Stilt	*Himantopus himantopus*	3	2	5
63	291	W	B148	Red-necked Avocet	*Recurvirostra novaehollandiae*	4	4	4
64	292	W	B147	Banded Stilt	*Cladorhynchus leucocephalus*	1	0	0
65	299	W	B143	Red-capped Plover	*Charadrius ruficapillus*	1	0	3
66	306	W	B144	Black-fronted Dotterel	*Elseyornis melanops*	14	13	14
67	308	W	B132	Red-kneed Dotterel	*Erythrogonys cinctus*	1	1	2
68	309	WL	B135	Banded Lapwing	*Vanellus tricolor*	1	0	5
69	310	W	B133	Masked Lapwing	*Vanellus miles*	3	3	2
70	333	W	B158	Common Greenshank	*Tringa nebularia*	1	1	0
71	350	W	B163	Sharp-tailed Sandpiper	*Calidris acuminata*	1	0	0
72	352	W	B161	Curlew Sandpiper	*Calidris ferruginea*	0	0	1
73	366	L	B018	Little Button-quail	*Turnix velox*	0	2	2
74	368	WL	B173	Australian Pratincole	*Stiltia isabella*	0	0	2
75	383	W	B111	Gull-billed Tern	*Gelochelidon nilotica*	0	0	6

Count	CB08	Zone	CODE	English Name	Scientific Name	2014	2015	2016
76	384	W	B112	Caspian Tern	*Hydroprogne caspia*	8	0	2
77	385	W	B110	Whiskered Tern	*Chlidonias hybrida*	0	1	2
78	403	W	B125	Silver Gull	*Chroicocephalus novaehollandiae*	1	2	0
79	408	L	B264	Red-tailed Black-Cockatoo	*Calyptorhynchus banksii*	1	2	0
80	415	L	B273	Galah	*Eolophus roseicapillus*	13	14	12
81	418	L	B271	Little Corella	*Cacatua sanguinea*	11	14	13
82	420	L	B274	Cockatiel	*Nymphicus hollandicus*	0	8	8
83	443	L	B297	Blue Bonnet	*Northiella haematogaster*	10	6	8
84	445	L	B295	Red-rumped Parrot	*Psephotus haematonotus*	5	5	4
85	452	L	B310	Budgerigar	*Melopsittacus undulatus*	10	13	14
86	454	L	B306	Blue-winged Parrot	*Neophema chrysostoma*	0	1	0
87	467	L	B348	Channel-billed Cuckoo	*Scythrops novaehollandiae*	0	0	1
88	468	L	B342	Horsfield's Bronze-Cuckoo	*Chalcites basalis*	8	9	13
89	469	L	B341	Black-eared Cuckoo	*Chalcites osculans*	0	1	2
90	472	L	B337	Pallid Cuckoo	*Cacomantis pallidus*	0	2	5
91	481	L	B242	Southern Boobook	*Ninox novaeseelandiae*	1	4	2
92	487	L	B249	Eastern Barn Owl	*Tyto javanica*	0	2	4
93	497	L	B325	Red-backed Kingfisher	*Todiramphus pyrrhopygius*	5	12	12
94	498	L	B326	Sacred Kingfisher	*Todiramphus sanctus*	1	1	3
95	523	L	B680	Spotted Bowerbird	*Ptilonorhynchus maculatus*	0	1	0
96	531	L	B535	White-winged Fairy-wren	*Malurus leucopterus*	11	12	11
97	532	L	B536	Variegated Fairy-wren	*Malurus lamberti*	12	14	13
98	539	L	B871	Grey Grasswren	*Amytornis barbatus*	2	2	1
99	547	L	B515	Eyrean Grasswren	*Amytornis goyderi*	1	2	5
100	591	L	B466	Southern Whiteface	*Aphelocephala leucopsis*	1	0	1
101	596	L	B570	Red-browed Pardalote	*Pardalotus rubricatus*	9	4	13

Count	**CB08**	**Zone**	**CODE**	**English Name**	**Scientific Name**	**2014**	**2015**	**2016**
102	597	L	B976	Striated Pardalote	*Pardalotus striatus*	13	3	5
103	600	L	B602	Pied Honeyeater	*Certhionyx variegatus*	1	0	2
104	609	L	B608	Singing Honeyeater	*Lichenostomus virescens*	2	3	4
105	623	L	B625	White-plumed Honeyeater	*Lichenostomus penicillatus*	15	14	14
106	628	L	B635	Yellow-throated Miner	*Manorina flavigula*	13	11	11
107	629	L	B640	Spiny-cheeked Honeyeater	*Acanthagenys rufogularis*	12	13	9
108	640	L	B449	Crimson Chat	*Epthianura tricolor*	5	7	7
109	641	L	B450	Orange Chat	*Epthianura aurifrons*	2	2	2
110	671	L	B598	Painted Honeyeater	*Grantiella picta*	0	2	0
111	674	L	B445	White-browed Babbler	*Pomatostomus superciliosus*	2	1	1
112	675	L	B446	Chestnut-crowned Babbler	*Pomatostomus ruficeps*	6	3	7
113	680	L	B439	Cinnamon Quail-thrush	*Cinclosoma cinnamomeum*	1	0	2
114	684	L	B866	Chirruping Wedgebill	*Psophodes cristatus*	8	6	7
115	688	L	B424	Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	7	14	13
116	692	L	B430	White-winged Triller	*Lalage sueurii*	3	3	8
117	699	L	B398	Golden Whistler	*Pachycephala pectoralis*	0	1	0
118	702	L	B401	Rufous Whistler	*Pachycephala rufiventris*	3	8	10
119	707	L	B408	Grey Shrike-thrush	*Colluricincla harmonica*	5	7	7
120	711	L	B671	Olive-backed Oriole	*Oriolus sagittatus*	0	1	0
121	712	L	B543	White-breasted Woodswallow	*Artamus leucorynchus*	13	14	13
122	713	L	B544	Masked Woodswallow	*Artamus personatus*	6	5	12
123	714	L	B545	White-browed Woodswallow	*Artamus superciliosus*	3	4	4
124	715	L	B546	Black-faced Woodswallow	*Artamus cinereus*	14	13	12
125	722	L	B705	Australian Magpie	*Cracticus tibicen*	9	9	11
126	730	L	B361	Grey Fantail	*Rhipidura albiscapa*	4	0	2
127	733	L	B364	Willie Wagtail	*Rhipidura leucophrys*	15	14	14

Count	**CB08**	**Zone**	**CODE**	**English Name**	**Scientific Name**	**2014**	**2015**	**2016**
128	737	L	B930	Australian Raven	*Corvus coronoides*	15	14	14
129	740	L	B691	Little Crow	*Corvus bennetti*	9	8	12
130	747	L	B369	Restless Flycatcher	*Myiagra inquieta*	0	1	2
131	753	L	B415	Magpie-lark	*Grallina cyanoleuca*	13	14	14
132	768	L	B381	Red-capped Robin	*Petroica goodenovii*	2	7	6
133	789	LW	B524	Australian Reed-Warbler	*Acrocephalus australis*	2	1	2
134	791	L	B523	Tawny Grassbird	*Megalurus timoriensis*	0	1	0
135	792	LW	B522	Little Grassbird	*Megalurus gramineus*	4	0	2
136	793	L	B509	Rufous Songlark	*Cincloramphus mathewsi*	1	1	8
137	794	L	B508	Brown Songlark	*Cincloramphus cruralis*	0	2	2
138	804	L	B358	White-backed Swallow	*Cheramoeca leucosterna*	14	13	14
139	806	L	B357	Welcome Swallow	*Hirundo neoxena*	2	2	1
140	807	L	B360	Fairy Martin	*Petrochelidon ariel*	12	8	12
141	808	L	B359	Tree Martin	*Petrochelidon nigricans*	13	13	14
142	824	L	B999	Common Starling	*Sturnus vulgaris*	1	0	0
143	829	L	B564	Mistletoebird	*Dicaeum hirundinaceum*	13	13	13
144	831	L	B653	Zebra Finch	*Taeniopygia guttata*	11	14	14
145	852	L	B995	House Sparrow	*Passer domesticus*	1	0	0
146	854	L	B647	Australasian Pipit	*Anthus novaeseelandiae*	3	2	6
147	217	W	B977	Cattle Egret	*Ardea ibis*			
148	237	L	B231	Black-breasted Buzzard	*Hamirostra melanosternon*			
149	257	L	B236	Grey Falcon	*Falco hypoleucos*			
150	305	WL	B145	Inland Dotterel	*Charadrius australis*			
151	593	L	B469	Banded Whiteface	*Aphelocephala nigricincta*			
152	644	L	B452	Gibberbird	*Ashbyia lovensis*			

Appendix 3 Brief description and midpoint of each transect/subsite

TransName	UTME_m	UTMN_m	Description
ANDRO	326045	7063925	Patchy, sparse Cool woodland, + one distribut channel crossed
ANDRR	326275	7063683	Cool +/- Qbt riparian woodland, W bank
ANDRS	325670	7064015	Cool lined minor channel over sparse Lig
BURTD	315635	7058200	Pale fringing dune w sparse Zyg. para & Ac. murr
BURTO	315933	7057888	Edge Lign minor WH & green ephem herbage
BURTP	316155	7057825	Open Lign over green ephem, fl/pl
BURTR	315665	7057930	Patchy Cool riparian w/l along two sm WHs
COWCD	233850	6942220	Pale orange dune, open A. lig shr/l w open Zyg. para
COWCF	233624	6943105	Patchy open omsb +/- Lign w patchy open Cool
COWCO	234295	6943438	Open Cool woodland over Lignum on fldpln
COWCR	234308	6943138	Cool riparian woodland over Lign, W bank
DBYDD	339150	7095490	Pale orng fringing dune w spares Acacia spp. over sparse Zyg. para
DBYDO	339365	7094208	Open Cool w/l over sparse Lig, fl/pl
DBYDP	339375	7095000	Open Cool w/l over Lign on minor distrib
DBYDR	339413	7093688	Cool +/- QBt riparian w/l over patchy BrWil, Lig, W bank
DBYDS	339360	7096365	Dense Cool +/- QBt riparian w/l over BrWil +/- Lig, W bank
DSPLD	339263	7078848	Open low A_lig shrbl over open Sh Canegr, pale orange dune, a few Cool along E edge
DSPLO	339638	7078788	Open Cool fldpn woodland over sparse RCoob, Lign
DSPLR	339985	7078432	Cool riparian woodland, N bank, W side of ?boundary fence, grazed
DSPLS	340510	7078330	Cool riparian woodland, N bank, E side of ?boundary fence, litely grazed
GOYLO	298428	7024140	Ecotonal gibber plain; sparse low herbl
GOYLP	297363	7023870	open Lig swamp/minor channel

TransName	UTME_m	UTMN_m	Description
GOYLR	298295	7024415	Open Cool riparian woodland over open Lign, S bank
GOYLS	296900	7023790	Open Cool riparian w/l over open Lign, S bank
KALAO	258178	6979783	omsb open shrbl w emerg Cool fldpl
KALAR	257555	6979770	Cool riparian woodland +/- BrWill, Lign, E bank
KALAS	258008	6979125	Cool riparian woodland over Lign, BrWill; distrib channels
KOOND	351500	7046768	SHCanegr open hum gr/l w emerg A_lig, dune
KOONO	351118	7046700	Lignum floodplain shrbl, S waterhole
KOONR	351073	7047320	Sparse Cool over BrWill tall shrbl riparian, sandy shore
KUNCD	251060	6970900	SHCanegr open grl, pale dunes
KUNCO	249383	6970765	Open Cool fldpn woodland
KUNCR	249698	6970640	Open Cool (thin strand) riparian woodland over Lign W bank
MIAMO	223300	6919805	Patchy, sparse (regen, few mature) Cool scalded fl/pl over sparse ephem herbage
MIAMR	222758	6919539	Cool (patchy) riparian woodland over BrWill, Lign, E bank
MIAMS	223015	6920143	Open Cool w/l over open Lig (broad minor channel)
MONAO	247723	6967595	barish floodplain w open forbl + sparse Lig, Qbb, Cool
MONAR	248245	6967425	Coolibah riparian w/l over BrWil, RCoob, Lign on Kallakoopah Ck
MONAS	247635	6966930	Coolibah riparian w/l over BrWil, RCoob, Lign on trib/distrib adj Kallakoopah Ck
PANDD	338868	7109913	Tr_bas+/-SHcanegr pale orange dune w emergent shrubs
PANDR	338500	7109783	Cool riparian woodland over Qbt, BrWill, E bank
PELID	323040	7062513	sparse A_lig Zyg_par mixed shr/grl on pale dune
PELIO	323118	7062970	sparse Cool, Lign, Scler sandy clayey plain
PELIR	322464	7062227	Thin strand Cool riparian w/l w sparse QBt, Er_big, Lign
PERID	352240	7061413	Sparse Zyg_para hum grl on low pale isolated dune
PERIO	352578	7061403	Open lign shr/l on damp greened-up edge of floodplain
PERIR	352094	7061433	Thin strand Cool riparian w/l over Lign along distrib channel

TransName	UTME_m	UTMN_m	Description
POOND	785240	6913323	Sparse Ac. Lig. shr/l over sparse Zyg. Para. hummock gr/l, dune
POONO	785698	6913358	Cool fldpln +/- riparian woodland over BrWill & Lign, E bank
POONR	786153	6912888	Open Cool riparian woodland over BrWill & Lign, S bank
STONG	256313	6959928	Sparse low herbl on stony gibber slopes
STONO	255380	6960545	Open Cool flpln woodland over RCoob, Lign
STONR	255020	6960618	Cool riparian woodland over BrWill & patchy Lign, E bank
STONS	255935	6960325	Cool riparian woodland +/- Lign, minor creek
TEPAD	299970	7049015	pale dune w sparse veg (mixed Acacia spp.)
TEPAO	299400	7047713	Open 'dead' Qbb low shrbl, patchy Lign clumps; cracking clay fldpl
TEPAP	300500	7049350	mod-dense omsb-Lign fl/pl
TEPAR	300218	7048205	Cool riparian woodland over BrWill, Lign, W bank
TINND	206783	6910913	Pale dune w sparse S/h can-gr & A. lig + adj shrubby i/d
TINNO	206930	6911807	Riparian (fairly thin, bit patchy) Coolibah woodland over lignum
TINNR	206651	6911583	Sparse (emergent) Cool over barish scalded plain w sandy veneer
TIPPD	302413	7012838	Zyg_para hum gr/l on jumbled orange dunes, + sparse Cool
TIPPR	302520	7012850	Open Cool, thin strand riparian w/l
ULTOD	276305	6994240	orange dune w open Zyg. para hum gr/l
ULTOO	275075	6994930	Low open Cool woodland over low open Lign, inner floodplain
ULTOP	276173	6993570	open omsb-Lign outer fl/pl
ULTOR	274763	6994913	Cool riparian woodland over BrWill-Lign, E bank
WADLD	219295	6913628	Open Zyg. par humm gr/l w emergent Ac. spp orange dune
WADLO	219283	6914550	Open Cool (regen, many dead trees) woodland, scalded fldpln
WADLR	219090	6914050	Open Cool riparian woodland, N bank
WADLS	219265	6915815	Cool riparian woodland over BrWill, Lign, S bank
YAMMD	345078	7065520	Sparse low mixed (Ac_lig) shrbl over SHCanegr & Tr_bas

TransName	UTME_m	UTMN_m	Description
YAMMF	345320	7064870	Barish floodplain, w dry, leafless sparse Qbb
YAMMH	344390	7066153	Open Cool flat/claypan, nr old HS ruins
YAMMO	345080	7065195	Open-sparse low Cool w/l over open-sparse Lign +/- (sticks) Qbb
YAMMR	344535	7065230	Cool riparian woodland, N bank
YAMMS	344088	7065945	Cool +/- QBt riparian w/l over BrWil, Lign, Plumb, E bank
YELLO	229135	6932928	Open Cool woodland over sparse het. shrbl over sandy open herbl
YELLR	229018	6932468	Open Cool riparian woodland over Lign, S bank
YELLS	228573	6932905	Cool riparian woodland over Lign, W bank
YELPD	272688	6997975	pale dune w sparse veg (mixed Acacia spp, sparse Cool on E flank)
YELPO	272310	6997960	low open Cool w/l over open Lign, Qbb fl/pl
YELPR	272985	6997725	Cool riparian w/l over BrWil, RCoob, Lig on Yelp distrib, Warburton R